United States
Department of
Agriculture

Forest Service

Northeastern
Area
State & Private
Forestry

NA-TP-10-01

Crop Tree Field Guide

Selecting and Managing Crop Trees in the Central Appalachians

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA'S TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence Avenue, SW, Washington, DC 20250-9410 or call (202) 720-5964 (voice or TDD). USDA is an equal opportunity provider and employer.

Crop Tree Field Guide

Selecting and Managing Crop Trees in the Central Appalachians

Arlyn W. Perkey
and
Brenda L. Wilkins

Northeastern Area
State and Private Forestry
USDA Forest Service
Morgantown, WV 26505

October 2001

ACKNOWLEDGEMENTS

Completion of this publication would not have been possible without the assistance of many colleagues, some of whom were giving advice when they didn't know it. Gary Miller, Clay Smith (retired), and John Baumgras from the Northeastern Research Station are ongoing sources of reliable information. Rod Whiteman with the Northeastern Area has contributed vital information from demonstration areas on federal land. Without Ken Carvell (retired) and Ray Hicks from West Virginia University, Division of Forestry, our understanding of the ecology of the central Appalachian forest would not be advanced to the degree it is today. Thank you Cynthia Huebner for your help with the hickories.

George Freeman and Richard Potts reviewed the publication from the perspective of well-informed landowners who, along with foresters and other natural resource professionals, are the target audience. Their insight into the needs of landowners is invaluable.

Thank you Ann Steketee, Nancy Lough, and Helen Wassick for all of your dedicated assistance preparing this product and distributing it to clients. Without your commitment to customer service, we wouldn't be able to deliver to our readers.

Thanks to state service foresters, private forest consultants, extension foresters, and industrial landowner assistance program foresters who work tirelessly with private landowners. With the turnover in land ownership, it often seems like the task of providing landowner education and on-the-ground technical assistance is never ending. To date, we have reached only a small percentage of the landowning public. Thank you for not giving up; current and future generations need your help.

Finally, thank you to the private landowners who manage their land responsibly to accomplish your goals while producing benefits for society. It appears we will be relying on you to produce an even larger portion of the goods and services we demand from our forests. If the percentage of landowners who actively manage their forestland is going to increase, your leadership will be required to make it happen.

TABLE OF CONTENTS

Introduction 1
Using this Publication 3
Black Cherry 11
White Ash 17
Yellow-Poplar 21
Northern Red Oak 25
Black Walnut 31
Sugar Maple 35
Red Maple 39
American Beech 43
White Oak 47
Chestnut Oak 53
Scarlet Oak 57
Black Oak 61
Shagbark Hickory 67
Mockernut Hickory 71
Pignut Hickory 73
Bitternut Hickory 75
Summary 78
Appendix A 81
Appendix B 83
Appendix C 85
Appendix D 88
Appendix E 93
Sources of Information 94

Photographs by Arlyn W. Perkey (except as noted)

Graphics by Nancy A. Lough

Editor: Brenda L. Wilkins

Two excellent dendrology web sites granted permission for use of photographs. They are:

Trees of Alabama and the Southeast
Auburn University
Auburn, Alabama
Dr. Lisa Samuelson, Mike Hogan, and Tom Stokes
School of Forestry and Wildlife Sciences
Photography by Mike Hogan and Todd Langston
forestry.auburn.edu/samuelson/dendrology/species_list.htm

and

University of Wisconsin–Madison
Madison, Wisconsin
Michael W. Clayton
Department of Botany
Photography by Michael Clayton and Darrin Kimbler
wisc.edu/botit/img/

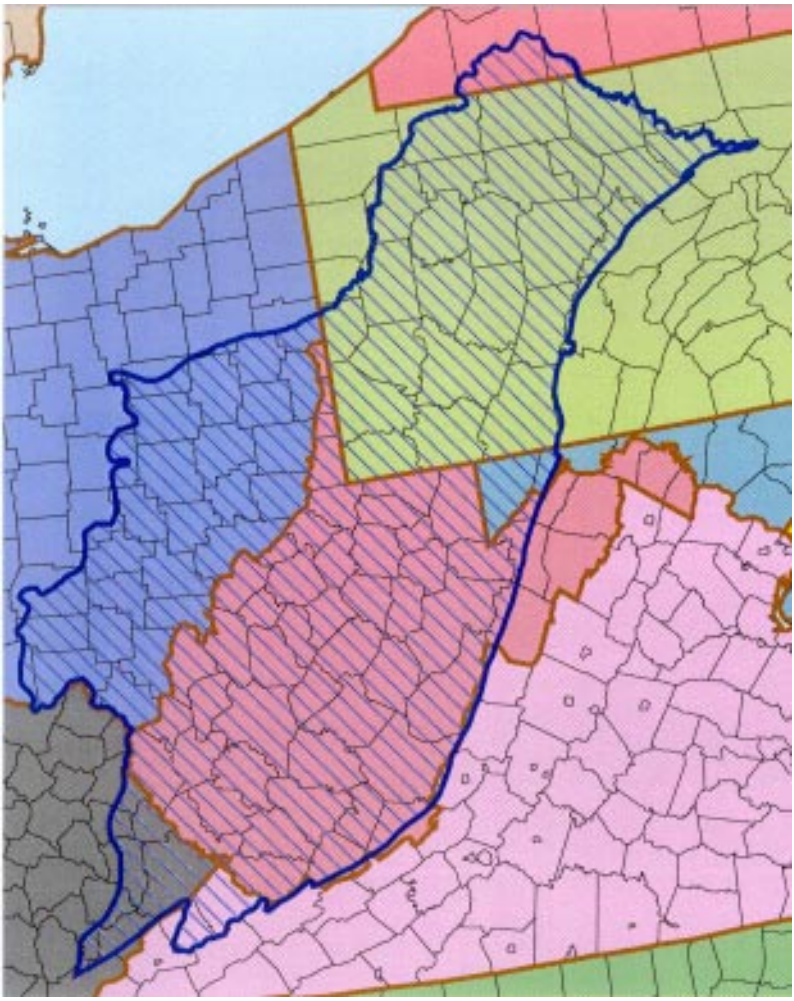
INTRODUCTION

This field guide was developed as an aid for foresters and landowners to facilitate selection of crop trees in the application of Crop Tree Management in the central Appalachian region of the United States. Managers familiar with the publication, *Crop Tree Management In Eastern Hardwoods*, will find this publication to be a source of additional guidance and information useful in selecting crop trees to accomplish desired landowner goals such as timber production, improved wildlife habitat, and enhanced aesthetic benefits.

Crop Tree Management promotes good stewardship of the forest resource. It offers landowners the opportunity to manage their woodland for multiple uses that will benefit themselves and society.

Based on research at the Fernow Experimental Forest, observations and growth data from several crop tree demonstration areas, and published sources of information, this guide provides greater detail for 16 individual species commonly selected as crop trees.

The map on the following page delineates the central Appalachian region where this guide is most applicable. Although it may be useful beyond the boundaries indicated, users outside of this zone must evaluate the relevancy according to their local growing conditions.



Area of Applicability

Central Appalachian Region
of the United States

USING THIS PUBLICATION

For ease of use, the 16 species covered in this guide are subdivided into four categories reflecting their frequency of association and the tendency for people to think of them as a group. For example, the CAP (Cherry, Ash, and Poplar) species are often found in coves in association with northern red oak and, occasionally, black walnut. The northern hardwoods are often found on cool sites. The dry site oaks and hickories are frequently neighbors. This organization makes it easier for the user to find information on trees on a given site. Just as they are commonly found growing together in nature, they are found close to each other in this publication.

Cool, Moist Sites

CAP-NRO-BW	Northern Hardwoods
Black Cherry	Sugar Maple
White Ash	Red Maple
Yellow-Poplar	American Beech
Northern Red Oak	
Black Walnut	

Warm, Dry Sites

Dry Site Oaks	Hickories
White Oak	Shagbark
Chestnut Oak	Mockernut
Scarlet Oak	Pignut
Black Oak	Bitternut

General Information Note:

There are many occasions when species from one group will be found in association with species from another. For example, red maple is often found on dry sites in association with dry site oaks and hickories. However, in these locations, it is less likely to have characteristics that will make it a timber crop tree candidate. Similarly, black walnut is frequently found on old-pasture, upland sites where it was a successful competitor. However, it seldom grows rapidly or produces quality products on these dry sites. Conversely, dry site oaks and hickories (especially bitternut) are found on moist sites. Because they produce hard mast (acorns and nuts), they may be considered valuable wildlife crop trees in these areas where winter-storable food is at a premium.

These categories are very general groupings of species on the sites where they are best adapted to being competitive and producing the highest value timber products.

To aid species identification, photographs featuring bark, bud, and leaf characteristics are included on the index pages that precede each species section. For some species, a picture of flower and fruit is also shown.

For most species, pole-size and larger trees can be identified by examining the bark. However, some of the hickories are an exception. Appendix D offers help in identifying the tight-bark hickories.

For some species, it is reasonable to imply general growth rate from the appearance of the bark. Where this is possible, photos that contrast growth rates are included to help the user assess crop tree potential and response.

Each species covered in this guide is described according to its potential to be selected as a timber, wildlife, and aesthetic crop tree. This information provides the basis for evaluation of individual trees according to the characteristics that qualify it for any of these three categories. It is possible that a tree might have qualities that place it in two, or even all three, crop tree categories.

The following format is used to give crop tree managers an easy way to locate this information by species.

Timber Crop Tree Notes –

- *Unit Value*
- *Growth Rate – usually expressed as diameter at breast height (dbh) growth in inches per decade*
- *Quality Comments – for some species*
- *Health Issues*
- *Natural Regeneration*

Wildlife Crop Tree Notes –

- *Mast Production*
- *Cavity Formation – for some species*

Aesthetic Crop Tree Notes –

- *Fall Foliage*
- *Spring Blossoms – for two species*
- *Size, Shape, or Form – for some species*

General Information Note:

Since the 16 species detailed in this guide tend to form root grafts with trees of the same species, caution must be used when applying herbicide to competing trees. Translocation of herbicide can occur, causing damage to the crop tree (backflash). Reactions to different herbicides varies among species, so it is best to be cautious about which herbicide to use with the individual species being treated. Caution in choosing the type of herbicide injected can reduce the risk of backflash. It is critical to read the label carefully. Consultation with professionals who have experience with injecting herbicides is also recommended.

For silvicultural treatments like site preparation for natural regeneration, it is possible to use backflash to great advantage. For example, where it may be desirable to deaden most of the maple in a given area, the tendency to backflash may facilitate accomplishing that objective. In this instance, it may be prudent to choose a herbicide that readily translocates through root grafts.

Herbicide information changes as new products are developed and labeled. Current advice is available in *Herbicide Hardwood Crop Tree Release in Central West Virginia* (Kochenderfer, et. al. - see *Sources of Information* on page 94). Online information is available at *Ohio State University <http://www.ag.ohio-state.edu/index.html> July 17, 2001.*

In this publication, where the terms *sapling, pole,* and *small, medium,* and *large sawtimber* are used, they are referring to tree size classes as described below.

Tree Size Class	Diameter at Breast Height (inches)
Sapling	2-4
Pole	6-10
Small Sawtimber	12-14
Medium Sawtimber	16-20
Large Sawtimber	20+

The majority of the information provided in this guide is applicable to releasing crop trees that are at least 25 feet tall. However, a section on natural regeneration is included because in some instances it is critical for crop tree managers to integrate regeneration considerations into crop tree selection and management decisions. For most central Appalachian hardwood species (yellow-poplar is the exception), regeneration is a process, not an event. These species often require several years to build up (the process) an inventory of well established seedlings prior to a significant disturbance that releases those seedlings. In contrast, yellow-poplar regeneration is usually in response to a single event (disturbance) that occurs at a specific point in time.

When most of the crop trees are within 15 to 20 years of maturity, it is important to consider what actions may be needed to facilitate the process of establishing desirable regeneration. Examples include deadening midstory and understory vegetation to provide suitable seedbeds, adjustment of treatments to coincide with bumper seed crops, and protection of seeds and seedlings from deer.

When cutting activities are performed for any hardwood species, it is impotant to cut low stumps (1 foot high or less) to increase the probability of having the highest quality sprouts.

Projected time to maturity can be estimated using the growth rate tables in Appendix C. For example, red oaks that are currently 15 inches dbh and expected to grow 3.6 inches per decade, are projected to be over 20 inches dbh in 15 years.

Regardless of crop tree age and time from maturity, it is critical to retain trees that can provide a high-quality source of seed for

the establishment of future crop trees. Information in Appendix E can be used to anticipate the seed longevity in the soil, frequency of good seed crops, initial seed-bearing age, optimum seed-bearing age, and longevity of trees.

For all 16 species, it is important to remember that the greatest seed production is on trees with vigorous crowns that are receiving full sunlight.

For each species, there are comments on health issues that are particularly relevant for that species. However, some health issues are more widespread and affect the whole forest. Grazing by domestic livestock affects the health and quality of growing crop trees and the establishment of the next generation of crop trees. To grow high-quality hardwood timber crop trees in the central Appalachian region, grazing by livestock is generally not a compatible use. Information in this guide is based on the assumption that livestock is excluded from the woods.

Deer exclosures in areas of high deer population are often necessary to provide protection from excessive deer browsing.

A high deer population can seriously interfere with the regeneration of many species. At moderately high levels, deer can shift the competitive advantage to species that are low on the browse preference list. The long-term solution to this problem is a reduction in the size of the deer

herd. For the short term, crop tree managers whose objectives include establishing regeneration may need to provide protection from excessive deer browsing. Currently, the most commonly used methods of protection are fencing and tree shelters.

In the central Appalachians, invasive exotic plants are an increasing threat to the establishment of regeneration. These weeds are usually most effectively able to spread during times of disturbance. When the forest canopy is opened, the additional sunlight on the forest floor provides opportunities for these aggressive plants to crowd native species. If there is significant threat that an invasive species can expand, it is recommended that the weed be contained prior to extensive opening of the canopy.

The Ailanthus pictured here was injected with herbicide to kill both the roots and top of this aggressive invader. Notice the Ailanthus on the right that still has green leaves. This "missed tree" will necessitate a follow-up treatment.

Appendices A and B provide graphics that will help users of this guide understand how to apply a crown-touching release to selected crop trees and how to adjust the intensity of cutting by adjusting the number of crop trees released. Appendix C provides a tally sheet and growth comparison charts that can be used to monitor crop tree growth. Appendix D gives information to help distinguish among the tight-bark hickories, and Appendix E provides seed production and tree longevity information.

It is hoped that the information contained in this guide will equip those working in the central Appalachian region of this country with the best information available for applying Crop Tree Management principles to benefit private forest landowners and society.

Many private landowners are unaware of the benefits their forestland can provide to them. Crop Tree Management is an easily understood system that facilitates communication between forestry professionals and woodland owners.

BLACK CHERRY

Black cherry is found on a variety of sites in the central Appalachians, but it grows best on cool, moist sites where the climate provides precipitation throughout the year. It is intolerant of shade, but seedlings are more tolerant than older trees.

Leaves are simple, alternate, elliptical, and finely toothed. A pair of glands on the petiole near the leaf base are a distinguishing feature.

Fruit is initially green, turning purple-black at maturity.

Bark is thin and smooth with horizontal lenticels when young; its color is olive-brown to reddish-brown (left).

As the tree grows older, it develops scales with recurved edges that become flaky (right).

Flowers are white and attractively complement fresh green foliage in the spring.

Buds are about 1/5 inch long. They are covered with shiny, reddish-brown to green colored scales. The twigs are red-brown and have a waxy bloom.

BLACK CHERRY

Timber Crop Tree Notes –

Unit Value: The per unit value of black cherry is very high, especially within the portions of its geographic range where it has traditionally grown into high-quality trees. Black cherry grows in many states in the eastern United States, but it is most valuable in all or portions of Pennsylvania, New York, Ohio, West Virginia, and western Maryland.

Growth Rate: Black cherry grows on a wide range of sites, but is commercially most valuable on cool, moist sites. Its early rapid height growth frequently provides an advantage over competing species. Only yellow-poplar has faster height growth on the best sites.

This pole-size black cherry is growing at the rate of 1.8 inches per decade. Notice the abundance of juvenile bark (lenticels visible) and the absence of red stretch marks between bark flakes.

This released, pole-size black cherry is growing at the rate of 3.5 inches per decade. Stretch marks between bark flakes indicate the trunk's surface area is expanding relatively rapidly.

On good sites, if it has a healthy, vigorous crown that is free-to-grow on three or four sides, black cherry can be expected to grow 2 to 4 inches per decade in diameter up to 50 years of age. After 50, it may still respond to release, but its diameter growth rate might be substantially less than other released, more tolerant associates in the stand. Black cherry does not recover well if it begins to lose the competitive race with adjoining trees. For best performance following release, it is important for crop trees to be young, have dominant or strong co-dominant crown class, and be on a cool, moist site. Released trees without these factors may deteriorate in vigor and value.

The seam below this fork is a weak point where this tree is most likely to split. This defect makes the tree a poor crop tree choice.

Quality Comments: The early rapid height growth of black cherry frequently puts it taller than the general crown canopy in mixed-species stands. This opens the way for forks to develop on the main stem. Seams below these forks indicate high risk for major value loss caused by the fork splitting apart in wind or ice storms.

Sapling and small pole-size trees are highly subject to bending by ice and wet snow, causing severe crooks in the stem and loss of the terminal leader. Black cherry does tend to recover after breakage in the crown with less

loss of diameter growth than might occur in other species.

Decay spreads more slowly in cherry than many associated species, so long-term effects may be less than they initially appear.

Black cherry has a fairly strong tendency to epicormic branch when released.

To reduce the probability of gum spots (a defect resulting in reduced timber quality) caused by bark beetles in black cherry, operations between January and June that result in black cherry slash or standing, dead trees should not be carried out. Black cherry trees cut or deadened between July and January are much less likely to provide suitable habitat for bark beetles.

Wild grapevines attach to trees, competing for sunlight and burdening branches with extra weight that often can't be supported.

It is critical to release black cherry crop trees from grapevines at an early age. It is more susceptible to damage by grapevines than other central Appalachian hardwood species. Black cherry crop trees with grapevines in their crowns are much

more likely to be severely damaged by breakage in ice and snow storms.

Health Issues: Black knot commonly causes cankers to develop on trunks and branches of black cherry trees. Large cankerous swellings (which can often be a foot or more in length) on the trunk of a tree can render it useless as a high-value product. Cankers are weak spots where the tree is subject to increased risk of breaking during wind and ice storms.

Black cherry trees with black knot on the trunk should generally be avoided when selecting crop trees for timber production. However, black knot in the crown can be accepted if less than 50 percent of the crown is affected (assume the branch will break off at the knot).

The cherry scallop shell moth is a defoliator of black cherry. If defoliation coincides with, or follows, other stress events such as drought or a late frost, crown dieback, loss of radial growth, or tree mortality may result.

Natural Regeneration: Maximum seed production in black cherry generally occurs between the ages of 30 and 100 years. Some individual trees never produce significant quantities of seed even when they reach the age and crown position where it is expected. In most stands of seed-bearing age, some seeds are produced almost every year. Good crops occur at 1 to 5 year intervals.

Songbirds distribute modest quantities of seed in their droppings or by regurgitation. Omnivorous mammals, such as foxes and bears, also distribute seeds in their droppings. Bird and mammal distribution often accounts for a surprising abundance of advance cherry seedlings in stands lacking cherry seed producers. Black cherry seed can remain viable in the soil for 3 years. Because of relatively frequent seed crops and delayed germination, often a considerable quantity of viable cherry seed is stored in the forest floor beneath cherry stands, freeing natural regeneration from dependency on current seed production.

Seedbed requirements for germination are not rigid. Mineral soil is not required. Germination is somewhat less on mineral soil than on undisturbed humus or leaf litter. A moist seedbed is required for good germination, and burial of seeds to a depth of several inches is beneficial. Shade also improves germination by helping to maintain stable moisture. Overstory stocking levels of 50 to 70 percent provide optimum conditions for establishment of black cherry advance reproduction.

Good germination and high survival provide for maximum seedling numbers at this level, and seedling heights of 1 to 2 feet are achieved in about 5 years. Best height growth of established seedlings, however, occurs in full sunlight. Black cherry advance seedlings more than 6 inches tall and at least 2 years old survive well and grow rapidly after exposure to full sunlight.

Black cherry will take advantage of canopy gaps to establish seedlings and saplings. To maintain rapid height and diameter growth, understory and midstory trees must obtain access to full sunlight found in the main crown canopy.

Black cherry is lower on the deer browse preference list than many associated species. Consequently, in moderately high deer population areas, establishment of black cherry regeneration is enhanced by deer browsing.

Wildlife Crop Tree Notes –

Mast Production: Black cherry fruits are an important source of mast for many nongame birds, squirrel, deer, bear, grouse, turkey, mice and moles, and other wildlife.

Aesthetic Crop Tree Notes –

Fall Foliage: The yellow fall foliage of black cherry is not impressive.

Size, Shape, or Form: To those who admire tall, straight trees, specimens with these characteristics are relatively common on good black cherry sites where the trees are forest grown.

WHITE ASH

White ash is found on fertile, moist, well drained soils. It is intolerant of shade.

Leaves are compound and opposite with 5-9 ovate leaflets that are grayish-white and lightly hairy below.

Bark is gray to brown with corky, interlacing ridges that form a diamond pattern. The gray-brown bark on young trees thickens with age as the furrows deepen and form sharp, interlacing ridges.

Fruit is a winged samara. The wing does not extend more than a quarter of the way down the body.

The opportunity to distinguish between male and female ash trees occurs in the early spring for 2-3 weeks when male flowers are visible, and prior to seedfall (September to December) when the fruit is on the female trees.

Terminal buds are brown, hairy, and have a powdery appearance. The leaf scar is U-shaped with opposite, lateral buds nestled within the scar.

WHITE ASH

Timber Crop Tree Notes –

Unit Value: White ash has a relatively high value as a timber crop tree when grown on suitable sites. Best growth occurs on moderately well drained soils where roots can penetrate to a depth of 16 inches or more. It has demanding soil fertility and soil moisture requirements. It grows best on soils with a high nitrogen content and moderate to high calcium content.

When wind-dispersed white ash seed germinates and establishes the species on dry upland, old-field sites, the result is often poorly formed, slow-growing trees similar to those pictured here. Releasing these trees will not produce high-value timber products.

Growth Rate: Post-juvenile diameter growth rates of 2.0 to 2.5 inches per decade can be expected on dominant and codominant trees in unthinned stands.

Released trees on suitable sites should grow 3 to 4 inches per decade. White ash is an early rapid grower in height and diameter. The best growth is achieved when it is less than 50 years old.

Quality Comments: White ash has a relatively low tendency to epicormic branch when released from competition, making it suitable to maintain in a free-to-grow condition while producing a high-quality product.

White ash often seeds in on old-field sites if there is an available seed source. Pioneer white ash on abandoned traditional agricultural land is usually poorly formed unless it developed in a dense stand that provided early competition to aid development of straight trees free of low forks.

Health Issues: In the northern part of its range, white ash has been plagued with a disease called ash yellows. The best prevention is to reduce plant stresses caused by water shortage and competition.

On old-field sites where white ash may occur in nearly pure stands, the suitability of the site should be evaluated. If it does not have the soil, moisture, and nutrient conditions conducive to good growth, conversion to other species should be considered.

Natural Regeneration: White ash seed remains viable in the soil for 3 years, germinating when conditions are favorable. When young, white ash is relatively shade tolerant. Seedlings can persist for a few years in moderately dense shade, and they respond quickly to open-

ings in the canopy. With increasing age, white ash becomes less tolerant of shade. To become successfully established, white ash seedlings must receive sunlight from above in a timely manner.

Wildlife Crop Tree Notes –

Mast Production: White ash is not normally selected as a wildlife crop tree because its soft mast is not of great value to many species of wildlife. However, it is of fair value to quail, songbirds, and rodents. The minimum seed-bearing age is about 20 years, and trees are often 8 to 10 inches in diameter at breast height before they flower abundantly. White ash has male and female trees, limiting seed-producing trees to about half the population. Approximately half of the female trees bear abundant seed crops every third year. Seedfall occurs between September and December, so it is available to wildlife during fall and early winter.

Improving wildlife habitat is an important objective for some forestland owners.

Cavity Formation: White ash has a tendency to form cavities, which increases the probability it will have potential den sites suitable for use as shelter for some species of wildlife.

Aesthetic Crop Tree Notes –

Fall Foliage: White ash has attractive yellow fall foliage that may have a purplish cast on some individual trees.

Size, Shape, or Form: Viewers who enjoy the aesthetic attributes of straight, tall trees may favor white ash as an aesthetic crop tree because of its generally good form on suitable sites.

Where white ash is mixed with other species, crop tree managers can often ensure increased species diversity in the future stand. By choosing crop trees that are well adapted to growing on the site, managers improve the vigor and value of the residual stand.

YELLOW-POPLAR

Yellow-poplar grows best on rich, moist sites. It is intolerant of shade.

Leaves are simple, alternate, shiny green above and pale below, with 4-6 lobes and a square, notched apex.

Bark transitions from gray with small, white, narrow patches when young to two-shaded gray with deepening furrows forming irregular lines.

Buds are smooth and green to purple in color with two valvate scales. The laterals are alternate and smaller.

Flowers are tulip-shaped and light green with orange blotches.

YELLOW-POPLAR

Timber Crop Tree Notes –

Unit Value: The unit value of yellow-poplar is modest, fluctuating with demand over the many years of use in this country. Historically, yellow-poplar has been regarded as a desirable species because it is softer and more workable than many hardwoods. Its generally desirable form, tall merchantable height, and relatively small crown enable it to produce fairly high volumes of timber per acre for a hardwood species. In recent years market interest in yellow-poplar has increased because of its suitability for use as laminated veneer lumber and oriented strand board.

Yellow-poplars with deep crowns (live crown ratios of ±40%) can grow very rapidly on sites with moist, well drained soils.

Growth Rate: Yellow-poplar has the potential to grow rapidly on the better sites where it is best adapted to developing into large diameter, straight trees. Its early rapid height growth often gives it a competitive advantage over other species on moist sites. Where it has a height advantage, it can develop a relatively deep crown capable of supporting a diameter growth rate of 3 to 5 inches per decade when released. In nearly pure

stands, either naturally or artificially established, yellow-poplar needs thinning at a relatively young age (small pole-size) to encourage the development of deep crowns. Otherwise, it tends to develop tall, straight trunks with exceedingly small crowns with limited ability to support increased diameter growth.

On moderately moist, well drained, loose-textured soils, few hardwood species come close to matching the volume of merchantable timber that yellow-poplar can produce. However, on upper, dryer slopes with limited soil depth, yellow-poplar often survives, but has a shorter life span, does not respond as well to release, and does not grow as large. It is also commonly found growing on old pasture sites where it seeded in after traditional agricultural use was abandoned.

Quality Comments: Yellow-poplar will develop epicormic branches, especially on sites where it is only marginally adapted to growing. However, it seldom increases the amount of epicormic branches in response to a crown-touching release. If there are epicormic branches on a yellow-poplar trunk, they will remain there and grow larger in response to a release, but new branches usually do not proliferate.

Health Issues: On good cove sites, yellow-poplar has relatively few serious insect and disease problems if the trees have vigorous crowns. However, yellow-poplar is subject to breakage during storms, and is especially susceptible to ice damage. Crowns with limbs that are

nearly perpendicular to the trunk are less likely to break when stressed with the weight of ice. Wild grapevines in the crown of a crop tree significantly increase its susceptibility to damage by breakage.

When the sap is running in the spring, yellow-poplar is very susceptible to logging damage. If a falling tree strikes a standing poplar, there is often considerable bark loss up and down the trunk of the standing tree.

Natural Regeneration: Yellow-poplar requires sunlight to regenerate. It is competitive on severely disturbed harvesting sites or where a natural event like a wind or ice storm has resulted in very open conditions. Yellow-poplar seed remains viable in the soil for 8 years. Seed germination and seedling development are better on mineral soils or well-decomposed organic matter than on thick, undecomposed litter layer. Since yellow-poplar seed dispersion begins in the fall, disturbances like logging during the dormant season favor establishment and development. Growing-season harvesting favors competing vegetation.

The minimum size of opening that can be used to establish yellow-poplar is fairly small. However, both diameter and height growth are retarded in openings smaller than 0.5 to 1 acre. Yellow-poplar is also successful at colonizing old fields that have been abandoned from traditional agricultural use if a seed source is within wind-dispersal range.

Wildlife Crop Tree Notes –

Mast Production: Yellow-poplar is not usually selected as a wildlife crop tree because it is of relatively low value to most wildlife species. However, the flowers do provide a valuable source of nectar for bees. For a few landowners, that could be a goal.

Aesthetic Crop Tree Notes –

Fall Foliage: Yellow-poplar has attractive yellow foliage in the fall. Whether that, along with the stately form of the tree, warrants designation as an aesthetic crop tree depends on the preferences of the individual landowner.

Spring Blossoms: Yellow-poplar has very attractive light green and yellow-orange blossoms that are often overlooked in forest-grown trees. Since flowering occurs after leaves are present, the display of blossoms is less spectacular.

Size, Shape, or Form: A forest-grown crop tree with a straight, tall trunk, clear of branches with a full crown accounting for 40 percent of the tree's height is striking in appearance. Those who appreciate trees with this form may find many impressive yellow-poplar trees to admire.

NORTHERN RED OAK

Northern red oak is found on a range of sites, but develops best on rich, moist sites. It is intermediate in shade tolerance.

Bark transitions from smooth and gray when young to flat, light gray ridges and black furrows when older.

Leaves are simple, alternate, and dark green above with 7-11 bristle-tipped lobes and sinuses that usually extend less than 1/2 way to the mid-rib.

Fruit is a barrel-shaped acorn about 1 inch long.

Buds are brown, angled, and smooth.

NORTHERN RED OAK

Timber Crop Tree Notes –

Unit Value: Northern red oak has high value as a timber crop tree, especially when grown on good sites. Although it is found in all topographic positions, it usually grows best on lower and middle slopes with north- and east-facing aspects, in coves and deep ravines, and on well drained valley floors. The most important factors determining site quality for northern red oak are depth and texture of the A soil horizon, aspect, and slope position and shape. The best sites are found on lower, concave slopes, north- and east-facing aspects, on soils with a thick A horizon, and a loam to silt loam texture.

This released northern red oak is growing at the rate of 4.2 inches per decade. The reddish-colored stretch marks indicate the bark is rapidly expanding as growth is accelerated.

Growth Rate: Growth rates of 2.0 to 2.5 inches per decade can be expected on dominant and codominant unreleased trees. Released crop trees with healthy, vigorous crowns can grow 3 to 4 inches per decade on dry and dry mesic sites (as described in *Using Diagnostic Plants To Evaluate Site Class)*, and up to 5 inches per decade on mesic and moist mesic sites.

Quality Comments: Northern red oak has a fairly strong tendency to epicormic branch when released. In one study where residual tree trunks were fully exposed to light, 12 percent of the trees had a reduced butt log grade following release.

Care must be taken to select and release crop trees with healthy, vigorous crowns in the main crown canopy and no epicormic branches on the butt log. Abundant dormant buds on the butt log are a strong indication that epicormic branches may develop, so trees with this condition should not be selected as timber crop trees.

On poorer sites, there is greater probability of epicormic branches developing on crop trees.

Genetics is another factor causing trees to sprout in response to additional light on their trunks.

Northern red oak crop trees should not be released immediately before or soon after defoliation by gypsy moth. Defoliation stresses the tree, greatly increasing the probability that epicormic branches will develop.

Wood tunneling by the red oak borer causes losses from defects and degrade of lumber. Maintaining tree vigor will reduce susceptibility to attack.

Health Issues: The most destructive defoliating insect attacking northern red oak is the gypsy moth. Although it can recover from a single defoliation, it may be weakened enough for disease or other insects to attack and kill it.

Drought in association with defoliation can greatly increase stress on trees and subject them to attack by secondary organisms like the twolined chestnut borer and Armillaria root rot.

Natural Regeneration: Northern red oak acorn germination occurs during the spring following seedfall. Best germination occurs when the acorns are in contact with or buried in mineral soil and covered by a thin layer of leaf litter.

Acorns on top of the leaf litter or mixed with litter generally dry excessively during early spring and lose their viability before temperatures are favorable for germination. Germination is followed by vigorous and rapid taproot development. If the taproot is able to penetrate the soil, seedlings survive considerable moisture stress later in the growing season.

This germinating red oak acorn shows the developing taproot going down and the shorter shoot going up. Initially, oaks put more energy resources into developing a viable root system. Extensive development of the foliage occurs later.

Once established under a forest canopy, northern red oak seedlings seldom remain true seedlings for more than a few years. Conditions such as fire, poor light, poor moisture conditions, or animal activity kill the tops, but not the roots. So the tree resprouts. This dieback and resprouting may occur several times, producing root systems from 10 to 15 years or more older than the tops.

The root system on this red oak is probably older than the top.

Northern red oak sprouts readily. More than 95 percent of the northern red oak in young stands is sprouts, either from advance reproduction or from stump sprouts of cut trees. New sprouts from advance reproduction arise when old stems are damaged (broken) during logging or other disturbances.

To compete successfully in new stands, stems of northern red oak advance reproduction must be large and have well established root systems. Height growth of new sprouts is related to the size of the old, damaged stem; the larger the old stem, the faster the new sprout will grow.

Sprouts of low origin are much less likely to develop decay than sprouts that originate high on the stump, but they tend to develop severe crook or sweep at the base. Early clump thinning may be desirable to improve potential quality.

Wildlife Crop Tree Notes –

Mast Production: Northern red oak begins to bear fruit at age 25, but it usually does not produce seeds abundantly until age 50. Good to excellent seed crops occur about every 2 to 5 years. Acorn production is highly variable among trees, even in good seed years. Some trees are always poor producers while others are reliably good producers.

Landowners who have the opportunity to visit their woodlot during a good seed crop year may want to identify the best producers. These are the best candidates for hard mast producing wildlife crop trees.

Crown size seems to be the most important tree characteristic affecting acorn production. Dominant or codominant trees with large, free-to-grow crowns produce more acorns than trees with small, restricted crowns.

Even in good years, only about 1 percent of the acorn crop is available for regeneration. Many acorns are consumed by insects; squirrels; small rodents; raccoons; bear; deer; and turkey, ruffed grouse, and other birds. They can eat or damage more than 80 percent of

the acorn crop in most years and virtually 100 percent in very poor years.

Large acorns are generally dispersed over only short distances. Gravity and the caching activities of squirrels and mice are the primary means of dispersal.

Aesthetic Crop Tree Notes –

Fall Foliage: Northern red oak is not usually regarded as an aesthetic crop tree. Its fall foliage initially turns a reddish color that transitions to brown prior to leaf fall.

Size, Shape, or Form: Straight, tall trees may qualify northern red oak as an aesthetic crop tree because of its form.

Red oak fall foliage is not usually spectacular, but it occurs after many other species have lost their adornment. The deep crown on this released crop tree has it well positioned for good growth.

BLACK WALNUT

Black walnut grows best on fertile, moist sites frequently found in north- and east-facing coves. It is intolerant of shade.

Bark transitions from gray-brown on young trees to deeply fissured brownish-black bark on older trees.

Leaves are alternate and pinnately compound. Usually, there is no terminal leaflet.

Fruit is a walnut enclosed by a thick, green husk.

Buds are short and blunt and usually have some pubescent scales.

BLACK WALNUT

Timber Crop Tree Notes –

Unit Value: Black walnut can have high per unit value, although worth is very dependent on the quality of the tree. Historically, black walnut has been regarded as a high-value species. In recent years consumer preference has shifted, and it does not currently enjoy the price status it once commanded.

Growth Rate: Black walnut is very site sensitive. On deep, well drained, loamy soils it can be expected to grow 3 to 5 inches per decade when released. However, it is also commonly found on old pasture sites where it seeded in after traditional agricultural use was abandoned. On upper slopes with limited soil depth, black walnut trees can survive, but they grow very slowly and usually have poor form.

In the central Appalachians, black walnut can be found growing on sites where it is not well adapted. This walnut growing on an upland site appears to be a good crop tree. However, looks can be deceiving. Seven years after this tree was evaluated, its condition had seriously deteriorated.

Quality Comments: Some epicormic branching can be expected on previously unreleased forest-grown trees. Epicormic branches usually occur above the butt log, with a greater tendency to produce branches on the south side of the released tree than on the north side.

Like many hardwoods, black walnut may produce epicormic branches in response to wounds. These epicormics were stimulated by pruning. (USFS Photo.)

Health Issues: In some areas, cankers are very common, especially on sites where the trees grow slowly. Cankers greatly decrease the value of the product and may predispose the tree to breaking at the canker location.

Natural Regeneration: Young black walnut seedlings are intolerant of shade and are seldom found under dense tree canopies. Regeneration develops primarily from seeds that squirrels bury and fail to recover. Normal winter temperatures usually cause the buried seeds to break dormancy the following spring. Natural walnut regeneration is unpredictable, requiring the right combination of seed source, moderate-sized canopy gaps, and sufficiently rich sites.

Ohio tree farmer Bill Lawhon started with deep, well drained soil and added high-quality seedlings that were kept cool and moist prior to planting. He used herbicides to reduce competition on the planting site. Follow-up release from weeds and corrective pruning produced this three-year-old potential crop tree.

Black walnut seldom occurs in pure stands unless it is planted. Successful plantations require labor-intensive care, especially during establishment when weed control and corrective pruning are needed to encourage rapid growth and development of straight, knot-free trunks.

Wildlife Crop Tree Notes –

Mast Production: Black walnuts are winter storable fruits that are preferred by squirrels and mice. Good seed crops are produced about twice every 5 years. Large seed crops do not usually occur until trees are about 30 years old, with production declining after 130 years of age.

Aesthetic Crop Tree Notes –

Fall Foliage: Black walnut does not have impressive fall foliage; the leaves just wither and fall.

SUGAR MAPLE

Sugar maple grows on moist, well drained soils. It is very shade tolerant.

Bark is light brown and smooth, becoming gray, furrowed, and plated on older trees.

Leaves are simple, opposite, and usually 5-lobed with round sinuses and very pointed lobes.

Buds are brown and pointed. Twigs tend to be shiny and red-dish-brown colored, displaying V-shaped leaf scars.

Fruit is a double samara, green to reddish-brown in color.

Photograph by Mike Clayton
Courtesy University of Wisconsin-Madison

SUGAR MAPLE

Timber Crop Tree Notes –

Unit Value: Sugar maple is intermediate in timber value. Historically, it has experienced periods of high value when consumer preferences favored light woods. An exception is a specialty wood product called birds-eye maple that has consistently demanded a premium price. Unfortunately, the development of this unique grain configuration is not well understood, so it can't be cultured. It is not easy to reliably recognize trees with this desired grain pattern, although there are a few suggestive bark characteristics that some experienced timber purchasers have learned to detect.

Growth Rate: Sugar maple height and diameter growth rates are slower than many associated species while it is young and in the pole stage of development. As it approaches middle age and small sawtimber-size, its

The sugar maple on the left is growing at the rate of 2 inches per decade.

The released sugar maple on the right is growing at the rate of 5 inches per decade. Notice the red stretch marks that indicate its rapid growth rate.

growth rate can exceed that of less shade tolerant competing species. Depending on site, released growth rates can vary from 2.5 to 5.0 inches per decade. Sugar maple grows best on well drained, loamy soils. It does poorly on dry, shallow soils. It is soil-site specific in the southern portion of its range. In the Appalachians, it often grows and regenerates best on north- and east-facing slopes.

On north- and east-facing lower slopes, Christmas fern is often abundant. Sugar maple usually grows well on these sites.

Quality Comments: On good sugar maple sites, epicormic branching is generally not a serious problem. On sites where trees are frequently stressed, evidence of epicormic branching on susceptible trees is usually visible (small branches).

Health Issues: Pear thrips have caused defoliation in Pennsylvania. Where outbreaks persist, growth decline and crown dieback can be expected.

Natural Regeneration: The optimum temperature for germination of sugar maple seeds is the lowest of any known forest species. Sugar maple can become established under a wide range of shade levels, but conditions must be cool and moist. It can become established in the shade of overstory trees that provide those conditions. However, it can also regenerate in open fields on north and east slopes where temperature and moisture remain within the acceptable range. Sawlog-size trees produce vast numbers of seeds. Sugar maple has a very high germination capacity, with averages of 95 percent or more. In natural stands, most seeds germinate after the first winter.

This open-grown, fence line sugar maple (center) was the seed source for these pole-size sugar maples on this north-facing slope. They became established in an open field because the site was cool enough for germination of sugar maple seed.

Wildlife Crop Tree Notes –

Mast Production: When buds are expanding, they are eaten by squirrels.

Cavity Formation: Sugar maple has a tendency to form cavities that will provide den sites suitable for use as shelter for some species of wildlife.

Aesthetic Crop Tree Notes –

These sugar maples qualify as both timber and aesthetic crop trees. Their brilliant fall foliage contrasts with the clear blue autumn sky.

Fall Foliage: Sugar maple is an outstanding aesthetic crop tree because of its very attractive fall foliage. Its leaves vary in color from yellow to orange, with a brilliance in color that is unmatched by any other species in the forest. Individual trees tend to turn the same color year after year. Therefore, a landowner who prefers trees that turn brilliant orange can favor those trees when making crop tree selections.

Size, Shape, or Form: Sugar maple is a long-lived species that can be 250+ years old and 30-36 inches in diameter. Open-grown trees found in pastures or along old fence lines frequently develop crowns that are attractive to many people.

RED MAPLE

Red maple occurs on a wide range of sites. It is intermediate in shade tolerance.

Bark is smooth and gray. It becomes broken, darker, and plated with age and increased size.

Leaves are simple, opposite, and 3-5 lobed. Petioles are often reddish, and leaves turn red or yellow in fall.

Buds are blunt and reddish-brown colored. Twigs are shiny, red, and have V-shaped leaf scars.

RED MAPLE

Timber Crop Tree Notes –

Unit Value: Red maple is intermediate to low in timber value, although it has had periods of higher value when consumer preferences favored light woods. It is sometimes substituted for sugar maple when the price of that species is high.

Growth Rate: Red maple growth rates are most rapid when it is young, and it slows down after trees pass the pole stage. It reaches maturity at age 70 to 80 years and seldom lives longer than 150 years. Red maple height and diameter growth rates are slower than many associated, less shade tolerant species. Depending on site, released crop trees can have diameter growth rates that vary from 2 to 3 inches per decade.

Red maple has a wide tolerance to climatic and site conditions. It is likely to survive on a wider range of soil types, textures, moisture, pH, and elevation than any other forest species in North America. It grows on diverse sites ranging from dry ridges and southwest slopes to peat bogs and swamps. Red maple commonly grows under the more extreme soil-moisture conditions; either very wet or quite dry. It does not show strong affinity for either a north or south aspect. Although it develops best on moderately well drained, moist sites at low to intermediate elevations, it is common in mountainous country on the drier ridges and on south and west exposures of upper slopes.

Quality Comments: Red maple is often poorly formed and defective, especially on poor sites. On good sites, however, it grows faster with better form and quality for sawlogs. Red maple has a moderate tendency to epicormic branch when given a crown-touching release.

Health Issues: Red maple is very sensitive to fire. Even large trees can be killed by a fire of moderate intensity. Surviving trees are very susceptible to damage caused by heart rots. Growing quality timber crop trees requires the exclusion of fire throughout the rotation.

Natural Regeneration: Red maple has few germination requirements. The seed can germinate with very little light, given proper temperature and some moisture. Most seeds germinate soon after dispersal in the early summer. Moist mineral soil seems the best seedbed for red maple, and a thin layer of hardwood leaf litter does not hinder germination and early survival. Many red maple seeds germinate each year in abandoned old fields, in cutover areas, and in the undisturbed forest.

Young seedlings are shade tolerant, so abundant 1- to 4-year-old seedlings are often found under the canopy of older stands. Many of these seedlings die each year if they are not released by opening of the main crown canopy, but new seedlings replace them. Thus, a reservoir of seedlings and ungerminated seed is available to respond to increased sunlight resulting from disturbance. Under favorable light and moisture conditions, red maple seedlings can grow 1 foot the first year,

and as much as 2 feet each year for the next few years. Some sprouts can grow 3 feet or more the first year.

Pre-existing red maples in a cut stand add greatly to the new stand stocking through stump sprouts. The number of sprouts per stump increases with stump diameter to a maximum of 9 to12 inches and then decreases among larger trees. Stumps of younger trees tend to produce taller sprouts. Many of the sprouts have rot and poor form, and they are only weakly attached to the stump.

Wildlife Crop Tree Notes –

Mast Production: Red maple is not normally selected as a wildlife crop tree because it has no particular characteristic that makes it uniquely valuable. However, it does provide a fairly reliable source of soft mast because a seed crop occurs almost every year, and on an average, a good to bumper crop occurs once every 2 years. Seeds are of fair value for songbirds, squirrels, and small rodents. Some trees are entirely male, producing no seeds; some are entirely female; and some are monoecious, bearing both male and female flowers. On monoecious trees, functioning male and female flowers usually are separated on different branches. Red maple buds are used by squirrels.

Cavity Formation: Red maple has a tendency to form cavities that will provide den sites suitable for use as shelter for some species of wildlife.

Aesthetic Crop Tree Notes –

Fall Foliage: In northern climates, red maple is an outstanding aesthetic crop tree because of its very attractive, brilliant red, fall foliage. In the Appalachians, its beauty pageant performance is less reliable, with fall coloration varying from yellow to red.

In the central Appalahian hardwood region, the color of red maple foliage can vary from red to yellow. Landowner preference is the primary factor in selecting aesthetic crop trees.

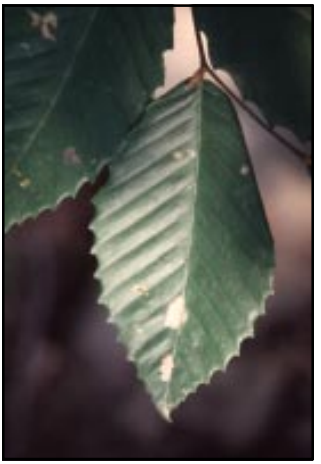
Spring blossoms: Red maple is one of the first trees to flower in the spring, generally several weeks before vegetative bud break. Many people enjoy this early display as it heralds the coming of spring. The reddish cast of the flowering crowns is not spectacular, but to many landowners it is a welcome visual indication that other more showy blossoms on other plants will soon follow.

AMERICAN BEECH

American beech is found on cool, moist sites. It is very shade tolerant.

Bark is smooth, thin, and steel gray.

Terminal Buds are distinctively long and pointed.



Leaves are alternate, simple, glossy dark green above and coarsely serrate with distinctively parallel lateral veins running to the margin teeth. Dead leaves commonly persist on twigs into the winter.

Fruit is triangularly shaped beechnuts contained in a spiny burr.

AMERICAN BEECH

Timber Crop Tree Notes –

Unit Value: Beech has a relatively low value as a timber crop tree. In the central Appalachian region, it is more abundant on the cooler and moister northern-facing slopes.

Growth Rate: Beech is generally regarded as a slow-growing tree that is very shade tolerant. The expected diameter growth rate of unreleased pole- and small sawtimber-size trees is 0.7 to 0.9 inches per decade. Partially released trees may average 1.5 to 1.9 inches per decade. Heavily released poles have been known to grow at rates of 2.2 to 3.0 inches per decade. Heavily released sawtimber-size trees have grown 3.0 inches per decade compared to 1.4 inches per decade for unreleased trees. Trees with vigorous crowns respond well to release.

Beech is regarded as a long-lived tree, but white oak and sugar maple generally outlive it.

Quality Comments: Beech trees prune themselves in well stocked stands. Open-grown trees, however, develop short, thick trunks with large, low, spreading limbs terminating in slender, somewhat drooping branches that form a broad, round-topped head. Trees that have been injured or suddenly exposed in a partial cutting often develop epicormic branches. Epicormic branching has also been observed after glaze damage.

Health Issues: The thin bark of beech trees renders it highly vulnerable to injury by fire, sunscald, logging, and pruning. When large branches are broken, they heal slowly, providing an avenue for decay. However, the most recent serious threat to beech in the central Appalachians is the beech bark disease. The largest trees are the most susceptible to mortality, and residual trees are often degraded in quality, making already low-value trees worth even less.

Small trees are often root suckers of older trees.

Natural Regeneration: Beech regeneration is very shade tolerant. Beech seedlings develop better under a moderate canopy or in protected small openings than they do on larger open areas where the surface soil may dry out below the depth of the shallow roots.

When forest stands are heavily cut, beech reproduction tends to grow more slowly than most associated hardwood species. This is especially true in a clearcut where the beech regeneration may be overtopped by less shade tolerant competing species. Heavy cutting or clearcutting results in fewer beech in the new stand than were present in the old stand.

Beech has the capacity to produce root suckers prolifically. Under partial cuttings, shade intolerant species offer little competition, and the shade tolerant beech reproduction is able to develop. The beech component may be further favored by its virtual immunity to deer browsing.

Wildlife Crop Tree Notes –

The smooth gray bark of large old beech trees makes these silvery giants aesthetically attractive. They frequently offer cavities for sheltering wildlife.

Mast Production: Beech mast is palatable to a vast variety of birds and mammals, including mice, squirrels, chipmunks, black bear, deer, foxes, ruffed grouse, ducks, and bluejays. In the maple-beech-birch association, beech is the only nut producer. Beech ordinarily produces a substantial amount of seeds when about 40 years old, and by the time it is 60, it may produce large quantities. Good beech seed crops are produced at 2 to 8 year intervals. Often, beech will produce seed burrs that are void of viable seed.

Cavity Formation: Beech has a tendency to form cavities that will provide den sites suitable for use as shelter for some species of wildlife. This is especially true where fire has caused wounds that provide entrance avenues for decay.

Aesthetic Crop Tree Notes –

Fall Foliage: Beech is seldom regarded as an aesthetic crop tree because of its fall foliage. However, its attractive, smooth, gray bark may warrant the tree such a classification. Unfortunately, the beech bark disease greatly reduces the beauty of affected trees that survive.

People often carve messages into the light, smooth bark of large beech trees, especially those located along trails and travelways.

WHITE OAK

White oak is found on fertile, well drained soils. It is intermediate in shade tolerance.

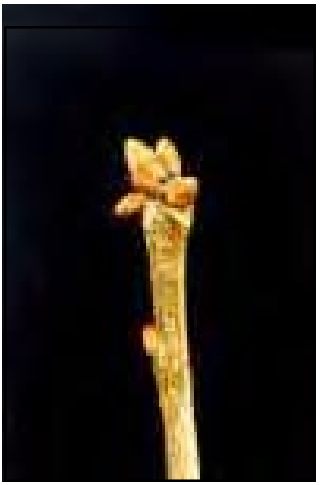
Leaves are simple and alternate with 7-10 round lobes. Lobes lack bristle tips, and sinuses vary from deep to shallow.

Fruit is an acorn about 3/4 inch long.

Bark is white to gray with some plates being loose and scaly.

White oak acorns are a highly preferred food source for many species of wildlife. Squirrels cut immature acorns from trees in mid-August.

Buds cluster on the ends of smooth twigs.



Photograph by Mike Hogan
Courtesy Auburn University

WHITE OAK

Timber Crop Tree Notes –

Unit Value: White oak has moderate value as a timber crop tree, especially when grown on good sites and in locations where epicormic branching is limited. White oak can grow in most topographic positions, but it is usually found on moderately dry slopes and ridges with relatively shallow soils. Although white oak grows more rapidly and produces more high-value products on lower and middle slopes with north- and east-facing aspects, it is usually not competitive on those sites. While smaller in size (at the same age), white oak is more abundant on the drier west- and south-facing slopes than on more moist sites.

Growth Rate: Growth rates of 1.1 to 1.7 inches per decade can be expected on dominant and codominant unreleased, small sawtimber-size trees. Released crop trees with healthy, vigorous crowns can be expected to grow 1.4 to 2.1 inches per decade on sites that average 73 feet tall (base age 50) for white oak.

White oak is intermediate in tolerance to shade. It is most tolerant in youth and becomes less tolerant as the tree becomes larger. White oak seedlings, saplings, and even pole-size trees are able to persist under a forest canopy. Saplings and pole-size trees respond well to release, and because of white oak's great longevity, it is able to obtain a competitive position in the overstory.

Although white oak has a strong tendency to epicormic branch, crop trees chosen from the main crown canopy with vigorous crowns and no evidence of epicormic branches on the butt log can avoid this problem. Seven growing seasons after release, the butt log of this crop tree is still free of epicormics and growing at 2.1 inches per decade.

However, trees deprived of adequate light for long periods of time, slowly grown, and suppressed or in intermediate crown classes may be especially prone to epicormic branching. Also, the ability of suppressed white oaks to respond to release diminishes as the period of suppression increases. Therefore, it is a good idea to limit the period of suppression.

Quality Comments: White oak has a strong tendency to epicormic branch when released. In one study where the cutting was very heavy, 24 percent of the trees had a reduced butt log grade following release. Care must be taken to select and release crop trees that have healthy, vigorous crowns in the main crown canopy and no existing epicormic branches on the butt log. Abundant epicormic branches on the second log are an indication that epicormic branches may develop on the butt log.

On poorer sites, there is greater probability of epicormic branches developing on crop trees. It is also likely that some trees are genetically predisposed to produce epicormic branches in response to additional light on their trunks.

White oak crop trees should not be released immediately before or soon after defoliation by gypsy moth. Defoliation stresses the tree and greatly increases the probability that epicormic branches will develop.

Health Issues: The most destructive defoliating insect attacking white oak is the gypsy moth. White oak can recover from a single defoliation, but may be weakened enough for attack by other insects or diseases that will kill it. Drought in association with defoliation can greatly increase the stress on trees and subject them to attack by secondary organisms like the twolined chestnut borer and Armillaria root rot.

Natural Regeneration: White oak acorn germination occurs during the fall, soon after dropping. When acorns germinate, their roots begin to grow, but the shoot remains dormant. After germination, root growth continues until interrupted by cold weather. Seedling establishment is best on loose soil because the radicle cannot penetrate excessively compact surfaces.

A humus layer is especially important because it keeps the soil surface loose and porous, and because it mechanically supports the acorn as the radicle penetrates the soil. Although important, soil moisture is probably not a critical factor in determining early seedling survival, except under unusually dry conditions.

The number of new white oak seedlings produced in any given year is low compared to other oaks, particularly black oak. However, these new individuals may persist in the understory for many years by repeatedly

dying back and resprouting. This phenomenon permits the gradual buildup of advance reproduction in the form of seedling-sprouts that are often taller and more numerous than the advance reproduction of associated oaks.

Small white oak trees stump sprout prolifically and vigorously when cut. Smaller trees are more likely to sprout than larger trees. Shoot elongation of stump sprouts increases with increasing stump diameter up to six inches, after which it declines. Annual height growth of stump sprouts after overstory competition is removed averages 2.2 feet. Low stump sprouts from pole-size trees and seedling-sprouts are about as good as trees grown from seed. However, sprouts originating high on the stump are likely to have heartwood decay.

The seedlings and seedling-sprouts already present in a mature stand (advance reproduction), together with stump sprouts, regenerate the stand following overstory removal. Although many stands may have adequate numbers of stems, the size of the reproduction when the overstory is removed is the key to adequate growth and successful competition with associated species.

Wildlife Crop Tree Notes –

Mast Production: White oak acorns are a highly preferred though inconsistent source of food for songbirds, squirrel, raccoon, and deer. Acorn crops are good in years when weather is warm for 10 days during flowering and then cool for 13 to 20 days afterward. The

acorn crop has been poor in years when cool periods preceded warm periods at the time of flowering. Acorns germinate almost immediately after falling to the ground in September or October.

White oak can produce seeds prolifically, but good acorn crops are irregular and occur only every 4 to 10 years. Sometimes several years will pass without a crop. Acorn production is highly variable among trees, even in good seed years.

Some trees are always poor producers while others are reliably good producers. In the open, white oak may begin to bear fruit at age 20, but trees normally bear seed between the ages of 50 and 200.

Light acorn crops are often completely destroyed by animals and insects, so seedlings are produced only during heavy crop years. Acorns are generally dispersed over only short distances. Widespread acorn production depends on adequate distribution of seed-bearing trees. Gravity and the caching activities of squirrels and mice are the primary means of dispersal.

Aesthetic Crop Tree Notes –

Fall Foliage: White oak is not usually regarded as an aesthetic crop tree. Its fall foliage initially turns a purplish-red color and then transitions to brown prior to leaf fall. Landowners who have open-grown trees may enjoy the aesthetic attributes of their dense foliage and broad, round crowns.

Note regarding the risk of backflash: Competing trees that are close to the crop tree (within 8 feet) are more likely to have a root graft with the crop tree. Trees more than 25 feet away are not likely to be root grafted.

Releasing crop trees by injecting competitors with herbicides can be accomplished with simple tools like a hand ax and spray bottle.

CHESTNUT OAK

Chestnut oak is found on dry, upland slopes. It is intermediate in shade tolerance.

Leaves are alternate and simple with shallow lobes.

Fruit is an acorn 1-1/2 inches long, narrow, and yellow-brown in color. The acorn cap covers half the nut.

Bark is deeply grooved on larger trees.

Terminal buds are large, smooth, and clustered on the ends of twigs.

Photograph by Darrin Kimbler
Courtesy University of Wisconsin-Madison

CHESTNUT OAK

Timber Crop Tree Notes –

Unit Value: Chestnut oak has moderate value as a timber crop tree, especially when grown on better sites and epicormic branching is at a minimum. Chestnut oak lumber is similar to and often marketed as white oak. Although chestnut oak grows best on rich, well drained soils, it is seldom competitive in getting established there. It is usually found on dry, upland sites such as ridgetops and upper slopes with shallow soils, south- and west-facing upper slopes, and sandy or rocky soils with low moisture-holding capacity.

Growth Rate: Growth rates of 1.1 to 1.7 inches per decade can be expected on dominant and codominant unreleased, small sawtimber-size trees. Released crop trees with healthy, vigorous crowns can be expected to grow an average of 2.3 inches per decade on dry and dry mesic sites (as described in *Using Diagnostic Plants To Evaluate Site Class*).

Chestnut oak is intermediate in tolerance to shade, similar in tolerance to white oak, but more tolerant than northern red, black, or scarlet oak. It is most tolerant in youth and becomes less tolerant as the tree becomes older.

Quality Comments: Chestnut oak has a strong tendency to epicormic branch when released. Care must be taken to select and release crop trees that have healthy, vigor-

ous crowns in the main crown canopy and no existing epicormic branches on the butt log.

Chestnut oak crop trees should not be released immediately before or soon after they have been defoliated by gypsy moth. Defoliation stresses the tree and greatly increases the probability that epicormic branches will develop.

Health Issues: The most destructive defoliating insect attacking chestnut oak is the gypsy moth. It and white oak are the two species most preferred by this exotic insect species. Chestnut oak can recover from a single defoliation, but may be weakened enough for disease or other insects to attack and kill it. Drought in association with defoliation can greatly increase the stress on trees and subject them to attack by secondary organisms like the twolined chestnut borer and Armillaria root rot.

Natural Regeneration: Chestnut oak acorn germination occurs during the fall, soon after dropping. When acorns germinate, their roots begin to grow, but the shoot remains dormant. After germination, root growth continues until interrupted by cold weather. Germination of chestnut oak acorns is enhanced by a covering of 1 inch of leaf liter. A covering of 2 inches results in many weakened seedlings. Large numbers of seedlings can become established after good seed crops, but such occurrences are infrequent. Chestnut oak acorns are more capable of germinating in dry soil than acorns of white, black, or northern red oak. Seedling establishment and survival are greatly reduced by dense herbaceous and shrub layers.

When tops die back or are damaged, chestnut oak seedlings and advance reproduction sprout vigorously from dormant buds at the root collar or on the stem. For stems of advanced reproduction that have been cut, the number of sprouts per plant and the growth of the sprouts increase with increasing size of the original stem and root system. Stumps of cut trees up to 60 years of age sprout vigorously, but the percent of stumps that sprout declines with increasing size for trees more than 18 inches in diameter. The incidence of decay is low for stump sprouts that originate within 2 inches of the ground, so these sprouts can develop into good crop tree candidates.

Wildlife Crop Tree Notes –

Mast Production: Chestnut oak acorns are a preferred though inconsistent source of food for songbirds, ruffed grouse, turkey, squirrel, mice, raccoon, and deer. Acorn crops tend to be good in years when temperature is above normal in late April followed by 13 to 20 days of below normal temperatures in early May. Uniformly increasing temperatures during this period usually result in poor pollination and small acorn crops.

Trees that produce a large crop of flowers and acorns one year usually produce fewer flowers the following year. Acorns fall to the ground from early September to early October, well before the acorns of other upland oaks are available. Heavy acorn crops are irregular and occur only every 4 to 5 years. Chestnut oak produces

fewer acorns than other upland oaks, although occasional trees can be prolific producers. Chestnut oak normally begins to bear fruit at age 20. However, stump sprouts as young as three years can produce viable seed, and stands with many sprouts may produce an abundant crop as young as age 7 or 8.

Chestnut oak produces fewer acorns than other upland oaks. Stump sprouts begin producing at an earlier age than seedings. Releasing sprouts in young stands is a means of getting more mast production sooner.

Aesthetic Crop Tree Notes –

Fall Foliage: Chestnut oak's fall foliage does not normally warrant it being classified as an aesthetic crop tree.

SCARLET OAK

Scarlet oak is common on poorer sites. It is intolerant of shade.

Leaves are simple and alternate with 5-7 bristle-tipped lobes and round sinuses extending more than halfway to the mid-rib. Leaves can be distinguished from northern red oak and black oak by their deeper sinuses.

Bark is black and fissured and may be streaked with white on the upper trunk. Swelling at the base is common.

Downward-arching and persistent dead branches are a distinguishing characteristic of scarlet oak.

Buds cluster on the ends of twigs. They are pointed and angled with white-silver hair on the upper half of the bud.

Photograph by Mike Hogan
Courtesy Auburn University

SCARLET OAK

Timber Crop Tree Notes –

Unit Value: Scarlet oak lumber is often mixed with that of other red oaks. Generally, it is less preferred as a timber crop tree than black or red oak because it is more likely to have grade defects. Dead branches frequently persist on the lower trunk, and the base of the tree often appears swollen or enlarged.

Immature scarlet oak often grows faster than its associates on dry sites. However, defects in the butt log sometimes develop and may be evidenced by bleeding sap and abnormal swelling.

Scarlet oak is generally found on light sandy and gravelly upland ridges and slopes. In the southern Appalachians, it regenerates and competes best on middle to upper slopes of southern exposure. However, site index increases with increasing depth of A horizon, and lower position on the slope. In the northern Appalachians, position on the slope, slope gradient, aspect, and soil depth to bedrock are also important site factors.

Growth Rate: Scarlet oak grows rapidly and matures early relative to many other species it is associated with on very dry sites. Average growth rates of 1.7 inches per decade can be expected on dominant and codominant unreleased trees.

Released crop trees with healthy, vigorous crowns can be expected to grow an average of 2.3 inches per decade on xeric (very dry) sites (as described in *Using Diagnostic Plants To Evaluate Site Class*). Scarlet oak responds well to release if the crop trees are very young and in the dominant or codominant crown classes.

Quality Comments: Scarlet oak has a strong tendency to retain dead branches relatively low on the trunk. These lower limbs that have succumbed because of shading usually have a distinctive downward curving appearance. If timber production is an objective, care must be taken to select and release crop trees with healthy, vigorous crowns in the main crown canopy and no existing large, dead branches on the butt log. Because of poor natural pruning, only one-third of scarlet oak potential crop trees originating from stump sprouts produce stems with desirable butt log quality, even on good sites.

Health Issues: Because of its thin bark, scarlet oak is very susceptible to fire damage. If not killed outright, the tree is usually injured, providing an entrance avenue for decay. Basal sprouting from fire-killed scarlet oaks may be prolific.

Even at an early age, heart rots can cause severe damage in scarlet oak by entering the trunk through persistent dead branch stubs. Heart rots are especially common in stump sprouts that originate high on the stump. Like other oaks, scarlet oak is subject to defoliation by the gypsy moth.

Natural Regeneration: A light covering of forest litter is beneficial to the germination of scarlet oak acorns. A moderately open overstory canopy provides a more favorable environment for acorn germination than either a completely open or closed canopy. Shoots of scarlet oak seedlings commonly dieback and resprout, forming seedling-sprouts. As a result of recurrent shoot dieback, root systems of scarlet oaks may be many years older than shoots. The potential rate of annual height growth of this reproduction increases with increasing basal diameter of sprouts. Young stump sprouts may produce up to three flushes of shoot growth per growing season. However, individual shoot flush lengths get progressively shorter as the season advances. After age 20, the rate of growth for sprouts declines.

Scarlet oak stumps produce sprouts at greater ages and larger sizes than most other oaks. They also produce a larger number of sprouts per stump, and these sprouts grow faster than those of most associated oaks, hickories, and red maple during the first 5 years. However, the percent of stumps that sprout decreases from nearly 100 percent for trees 4 inches dbh and smaller to about 18 percent for trees 24 inches dbh. In an Appalachian study, 28 percent of scarlet oak stump sprouts had butt rot, and sprouts from large stumps were more subject to decay than sprouts from small stumps.

Sprouts of low origin are much less likely to develop decay than sprouts that originate high on the stump.

Early clump thinning to one stem may be desirable to improve potential quality and increase growth and survival of the remaining stem.

Wildlife Crop Tree Notes –

Mast Production: In forest stands, scarlet oak begins to bear fruit at age 20, and maximum production does not occur until after 50 years of age. It produces good crops of acorns every 3 to 5 years.

Scarlet oak acorns are a choice food for eastern gray squirrels, chipmunks, mice, wild turkey, deer, and several species of birds – especially blue jays and red-headed woodpeckers. One-third to one-half of the acorn use by wildlife is attributed to removal by birds and squirrels while the acorns are still on the tree.

Aesthetic Crop Tree Notes –

Fall Foliage: Scarlet oak is often regarded as an aesthetic crop tree because of its attractive foliage. Mixed with other oak species, scarlet oak will stand out with its brilliant red autumn color and open crown texture.

BLACK OAK

Black oak is found on a variety of sites. It is intermediate in shade tolerance.

Younger bark on left. Older bark on right.

Bark develops a blocky texture at the base that expands upward as the tree ages. The inner bark is yellow-orange in contrast to the inner bark of similar species, like northern red oak and scarlet oak, which is a dull orange-brown.

Leaves are simple, alternate, and variable in shape with 5-7 bristle-tipped lobes.

Buds are light brown and angled, and they generally tend to be woolly.

BLACK OAK

Timber Crop Tree Notes –

Unit Value: Black oak has high value as a timber crop tree, especially when grown on good sites. It is often sold as red oak. It grows best on moist, rich, well drained soils, but it is often found on poor, dry, sandy or heavy glacial clay hillsides. The most important factors determining site quality for black oak are depth and texture of the A soil horizon, texture of the B horizon, aspect, and slope position. Black oak grows best on well drained, silty clay to loam soils.

On young black oak trees (left), the bark starts to develop the blocky texture that will characterize it later in life. Young red oak trees (right) have smoother bark that will transition into a more plate-like texture as the tree matures.

Growth Rate: Growth rates of 2 inches per decade can be expected on dominant and codominant unreleased trees. Released crop trees with healthy, vigorous crowns can be expected to grow 3 to 5 inches per decade on dry and dry mesic sites (as described in *Using Diagnostic Plants To Evaluate Site Class*). Black oak becomes physiologically mature at about 100 years of age. Some individuals may live to be 150 to 200 years old.

Black oak responds well to release if the crop trees are in the dominant or codominant crown classes. The best response is obtained if trees are first released when less than 30 years old so they are able to develop deep, vigorous crowns. Trees in stands older than 30 years that have always been fully stocked generally have small crowns that have been restricted too long. Because of this, they are unable to make efficient use of the growing space provided by release.

The distinctive elongated plates in the bark of red oak (foreground) help distinguish it from the black oak (background). Red oak crop trees have a longer life expectancy than black oaks.

Quality Comments: Black oak does have a fairly strong tendency to epicormic branch when released. Care must be taken to select and release crop trees that have healthy, vigorous crowns in the main crown canopy and no existing epicormic branches on the butt log. Abundant dormant buds on the butt log are a strong indication that epicormic branches may develop. On poorer sites, there is greater probability of epicormic branches developing on crop trees. It is also likely that some trees are genetically predisposed to produce epicormic branches in response to additional light on their trunks.

Black oak crop trees should not be released immediately before or soon after they have been defoliated by gypsy moth. Defoliation stresses the tree and greatly increases the probability that epicormic branches will develop.

Health Issues: The most destructive defoliating insect attacking black oak is the gypsy moth. Black oak can recover from a single defoliation, but may be weakened enough for disease or other insects to attack and kill it. Drought in association with defoliation can greatly increase the stress on trees and subject them to attack by secondary organisms like the twolined chestnut borer and Armillaria root rot.

Natural Regeneration: Black oak acorn germination occurs during the spring following seedfall. Best germination occurs when the acorns are in contact with or buried in mineral soil and covered by a thin layer of leaf litter. Acorns on top of the leaf litter or mixed with litter generally dry excessively during early spring and lose their viability before temperatures are favorable for germination. The primary root generally grows vigorously following germination. Seedlings can survive drought conditions, but growth is slow or even ceases altogether. Black oak seedlings are more drought tolerant than northern red oak seedlings.

Once established under a forest canopy, black oak seedlings seldom remain true seedlings for more than a few years. Conditions such as fire, poor light, poor moisture conditions, or animal activity kill the tops, but

not the roots. So the tree resprouts. This dieback and resprouting may occur several times, producing root systems from 10 to 20 years or more older than the tops.

Black oak sprouts readily. More than 95 percent of the black oak in young stands originates from sprouts, either from advance reproduction or from stump sprouts of cut trees. New sprouts from advance reproduction arise when old stems are damaged (broken) during logging or other disturbances. To compete successfully in new stands, stems of black oak advance reproduction must be large and have well established root systems. Height growth of new sprouts is related to the size of the old, damaged stem; the larger the old stem, the faster the new sprout will grow.

Black oak stumps sprout less frequently than those of northern red, scarlet, and chestnut oak and with about the same frequency as those of white oak. Small stumps from young trees on good sites sprout most frequently, while large stumps from old trees on poor sites sprout least frequently.

Sprouts of low origin are much less likely to develop decay than sprouts that originate high on the stump, but they tend to develop severe crook or sweep at the base. Early clump thinning may be desirable to improve potential quality.

Oak is a favorite species on the deer food preference list, so areas with a high deer population are often heavily browsed. Stump sprouts are especially vulnerable because they are preferred over seedlings.

Wildlife Crop Tree Notes –

Mast Production: In forest stands, black oak begins to bear fruit at age 20 and reaches optimum production at 40 to 75 years. It is a consistent seed producer with good crops of acorns every 2 to 3 years.

Acorn production is highly variable among trees, even in good seed years. Some trees are always poor producers while others are reliably good producers.

Even in good years, only a small percentage of the acorns become available for regeneration. Many acorns are consumed by insects, squirrels, small rodents, deer, turkey, ruffed grouse, and songbirds. They can eat or

damage a large percentage of the acorn crop in most years and virtually 100 percent of the crop in very poor years.

The acorns are generally dispersed over only short distances. Gravity and the caching activities of squirrels and mice are the primary means of dispersal. Blue jays may disperse over a longer distance.

Aesthetic Crop Tree Notes –

Fall Foliage: Black oak is not usually regarded as an aesthetic crop tree.

SHAGBARK HICKORY

Shagbark hickory is common on upland sites. It is intermediate in shade tolerance.

Bark is slate gray and smooth on young trees.

It breaks into dark gray, loose, longitudinal strips on older and larger trees.

Leaves are alternate and pinnately compound with 5 obovate leaflets.

Terminal Buds are about 3/4 to 1 inch long with persistent, loose-fitting outer scales that have divergent tips.

SHAGBARK HICKORY

Timber Crop Tree Notes –

Unit Value: Shagbark hickory has low value as a timber crop tree because of its slow growth and relatively low unit value. Although hickory lumber is attractive in cabinets and furniture, it has not commanded prices comparable to maple or oak. Hickory has traditionally been very popular as fuelwood and charcoal-producing wood. It has high heat value, burns evenly, and produces long-lasting, steady heat. The charcoal gives food a hickory-smoked flavor.

In the central Appalachians, shagbark hickory is usually found on dry, upland sites such as ridge tops and upper slopes with shallow soils, south- and west-facing upper slopes, and rocky soils with low moisture-holding capacity.

Growth Rate: The growth rate of shagbark hickory crop trees with vigorous crowns is faster than other hickories, but it is still a slow-growing species. There is little data available to compare growth rates on released versus unreleased crop trees. However, information from southern Indiana and northern Kentucky indicate that average growth rates for trees between the ages of 10 and 90 varies from 1.1 inches per decade to 1.6 inches per decade with growth generally slowing on older trees.

Health Issues: Shagbark hickory is susceptible to damage by fire at all ages. Light fires can result in topkill of reproduction and saplings (most of which later sprout). Hotter fires may kill larger trees and wound others.

Natural Regeneration: Shagbark seedlings normally produce a long taproot and very little top growth during early development. This competitive strategy is effective on dry sites where the seedlings establish a well developed root system before developing an elaborate top.

Shagbark hickory is a prolific stump sprouter as evidenced by these three stems that originated from a stump that has now decayed.

Shagbark hickory is a prolific sprouter. Nearly all of the cut or fire-killed hickories with stump diameters up to 8 inches will produce sprouts. As stump diameters increase, stump sprouting declines, and the proportion of root suckers increases. Young hickory sprouts are vigorous and can maintain a competitive position in the canopy of a newly regenerated stand. After 10 to 20 years, the rate of sprout height growth declines and hickory usually loses crown position to faster growing oaks and other species. To maintain a significant hickory component in mixed stands, it may be necessary to release hickory crop trees before they lose their competitive crown position.

Wildlife Crop Tree Notes –

Mast Production: Shagbark hickory reaches productive seed-bearing age at 40 years, with maximum production from 60 to 200 years. Good seed crops occur at intervals of 1 to 3 years with light crops or no seed during the intervening years. Tree diameter and crown size or surface are probably the best indicators of seed production.

Nuts are dispersed from September through December, with squirrels and chipmunks playing a role in expanding dispersal beyond where gravity places them. Shagbark nuts are heavily used by mice and deer. The nuts are also edible by humans.

Dispersal of nuts is expanded by squirrels and chipmunks. The hickory nuts they don't eat, they bury. Often, they never retrieve them, unknowingly planting and playing a role in the regeneration process.

Aesthetic Crop Tree Notes –

Fall Foliage: Shagbark hickory's fall foliage can be attractive, and depending on what other species are available, it may warrant being classified as an aesthetic crop tree.

Size, Shape, or Form: The bark of the shagbark hickory is distinctive and unique; no other species has such a shaggy appearance. It is one of a kind!

At the pole-size of development, the shagbark hickory's bark is becoming prominent enough to make it "stand out" in a crowd.

MOCKERNUT HICKORY

Mockernut hickory is found on upland sites. It is intolerant of shade.

Leaves are pinnately compound, alternate, and have 7-9 obovate leaflets. Leaves and rachis are hairy.

Bark is gray with interlacing ridges.

Terminal buds are 1/2 to 3/4 inches long, egg-shaped, silky, and yellow to tan in color. The outer bud scales fall early. Twigs are stout and hairy.

MOCKERNUT HICKORY

Timber Crop Tree Notes –

Unit Value: Mockernut timber value is similar to that of shagbark hickory.

Growth Rate: Mockernut hickory has slow diameter growth. Dominant and codominant trees with healthy, vigorous crowns can be expected to grow only about 1.2 inches per decade. There is little data available to compare growth rates on released versus unreleased crop trees.

Health Issues: Mockernut hickory is extremely susceptible to damage by fire because of the low insulating capacity of the hard, flinty bark.

Natural Regeneration: Hickory nuts seldom remain viable in the ground for more than 1 year. Hickory species normally require a moderately moist seedbed for satisfactory seed germination, and mockernut hickory seems to reproduce best in moist duff. Seedlings are not fast growing. Mockernut hickory sprouts prolifically from stumps after cutting and fire. As stump diameters increase in size, stump sprouting declines. Its competitive strategy is similar to shagbark hickory.

Wildlife Crop Tree Notes –

Both mockernut and pignut hickory are most competitive on dry, upland sites like this one. From a distance these trees are difficult to distinguish. Bitternut hickory is adapted to growing on more moist sites.

Mast Production: Mockernut hickory requires at least 25 years to reach good seed-bearing age. Optimum seed production occurs from 40 to 125 years. Good seed crops occur at intervals of 2 to 3 years with light crops during the intervening years.

The nuts are dispersed from September through December, with squirrels and chipmunks playing a role in expanding dispersal beyond where gravity places them. Mockernuts are heavily used by squirrel, small rodents, raccoon, turkey, and deer. Black bear, fox, rabbit, and beaver also use the hard mast. Unlike the small but meaty shagbark hickory nuts, mockernut hickory nuts yield smaller amounts of edible food for the effort it takes to crack the large "deceiving" nuts.

Aesthetic Crop Tree Notes –

Fall Foliage: Mockernut hickory's fall foliage can be attractive, and depending on what other species are available, it may be considered an aesthetic crop tree.

PIGNUT HICKORY

Pignut hickory is found on upland sites. It is intermediate in shade tolerance.

Leaves are alternate, hairless, and pinnately compound with 5-7 obovate leaflets.

Bark is gray-brown with interlacing ridges.

Terminal buds of pignut hickory are generally smaller, and twigs are more slender than those of mockernut hickory. Twigs are red-brown, smooth, and slender.

PIGNUT HICKORY

Timber Crop Tree Notes –

Unit Value: The timber value of pignut hickory is similar to that of shagbark hickory.

Growth Rate: Pignut hickory has slow diameter growth. Dominant and codominant trees with healthy, vigorous crowns can be expected to grow only about 1.2 inches per decade. There is little data available to compare growth rates on released versus unreleased crop trees.

Health Issues: Pignut hickory is easily damaged by fire.

Natural Regeneration: Hickory nuts seldom remain viable in the ground for more than 1 year. Seedlings are not fast growing. Hickory sprouts readily from stumps and roots. As stump diameters increase in size, stump sprouting declines. Root sprouts are vigorous and probably more numerous than stump sprouts in cutover areas.

Wildlife Crop Tree Notes –

Mast Production: Pignut hickory begins to bear seed in quantity at about 30 years with optimum seed-bearing age between 75 and 200 years. Good seed crops occur every year or two with light crops during intervening years. Frost can seriously hinder seed production.

Nuts are dispersed from September through December, with squirrels and chipmunks playing a role in expanding dispersal beyond where gravity places them.

Pignuts are heavily used by squirrel, small rodents, raccoon, turkey, and deer. Black bear, fox, rabbit, and several species of songbirds also use the hard mast.

Aesthetic Crop Tree Notes –

Fall Foliage: Pignut hickory's fall foliage can be attractive, and depending on what other species are available, this characteristic may qualify this species as an aesthetic crop tree.

BITTERNUT HICKORY

Bitternut hickory is found on moist, well drained soils. It is intolerant of shade.

Bark is smooth on young trees.

It transitions to interlacing ridges on older trees.

Leaves are alternate and pinnately compound with 7-11 generally lanceolate leaflets.

Terminal Buds are 1/2 inch long, bright yellow, and valvate.

BITTERNUT HICKORY

Timber Crop Tree Notes –

Unit Value: Bitternut hickory is a pecan hickory as opposed to a true hickory like shagbark and mockernut. It is cut and sold in mixture with the true hickories, but it is not equal to them in strength, hardness, and toughness. It is also less desirable for charcoal and fuelwood.

Growth Rate: Like other hickories, bitternut has slow diameter growth, but it has the shortest lifespan – about 200 years. Dominant and codominant trees with healthy, vigorous crowns can be expected to grow only about 1.2 inches per decade in the central Appalachian region. There is little data available to compare growth rates on released versus unreleased crop trees.

Health Issues: Bitternut hickory is susceptible to damage by fire because of the low insulating capacity of the hard bark.

Natural Regeneration: Establishing hickory trees from seedlings is difficult because of seed predators. Infrequent bumper seed crops usually provide some seedlings, but seedling survival is poor under a dense canopy. Seedlings are not fast growing.

Hickory species normally require a moderately moist seedbed for satisfactory seed germination, and bitternut hickory can probably tolerate a more moist seedbed than most other hickories.

Because of its prolific sprouting ability, hickory reproduction can survive browsing, breakage, drought, and fire. Top dieback and resprouting may occur frequently, with each successive shoot attaining a larger size and developing a stronger root system than its predecessors. By this process, hickory reproduction gradually accumulates and develops under moderately dense canopies, especially on sites dry enough to restrict reproduction of more tolerant, but more fire- or drought-sensitive species.

Bitternut hickory is the most prolific root and stump sprouter of the northern species of hickory. Most sprouts from sapling and pole-size trees are at the root collar, and sprouts from sawtimber-size trees are root suckers.

Of the four hickories covered in this guide, bitternut hickory is the one most frequently found on moist sites where hard mast production is often more limited.

Wildlife Crop Tree Notes –

This bitternut hickory may be regarded as an aesthetic crop tree because of its attractive foliage and tall, straight stature.

Mast Production: Bitternut hickory does not produce seed abundantly until it is about 30 years old. Optimum production extends from 50 to 125 years. Good seed crops occur at intervals of 3 to 5 years with light crops during the intervening years.

The nuts are dispersed from September through December, with gravity being the most significant dispersal agent. The seed is generally less tasteful to wildlife than the other hickories. Bitternuts are used by squirrel, but do not constitute a large portion of their diet. They may also be used by mice and deer.

Aesthetic Crop Tree Notes –

Fall Foliage: Bitternut hickory's fall foliage can be attractive, and depending on what other species are available, it may be considered an aesthetic crop tree.

APPENDIX A

Crop Tree Management focuses on selecting and releasing crop trees that meet criteria based on the landowner's goals and objectives for the property. To do this, a crown-touching release must be applied to each of the timber and most of the wildlife and aesthetic crop trees selected to produce the identified benefits.

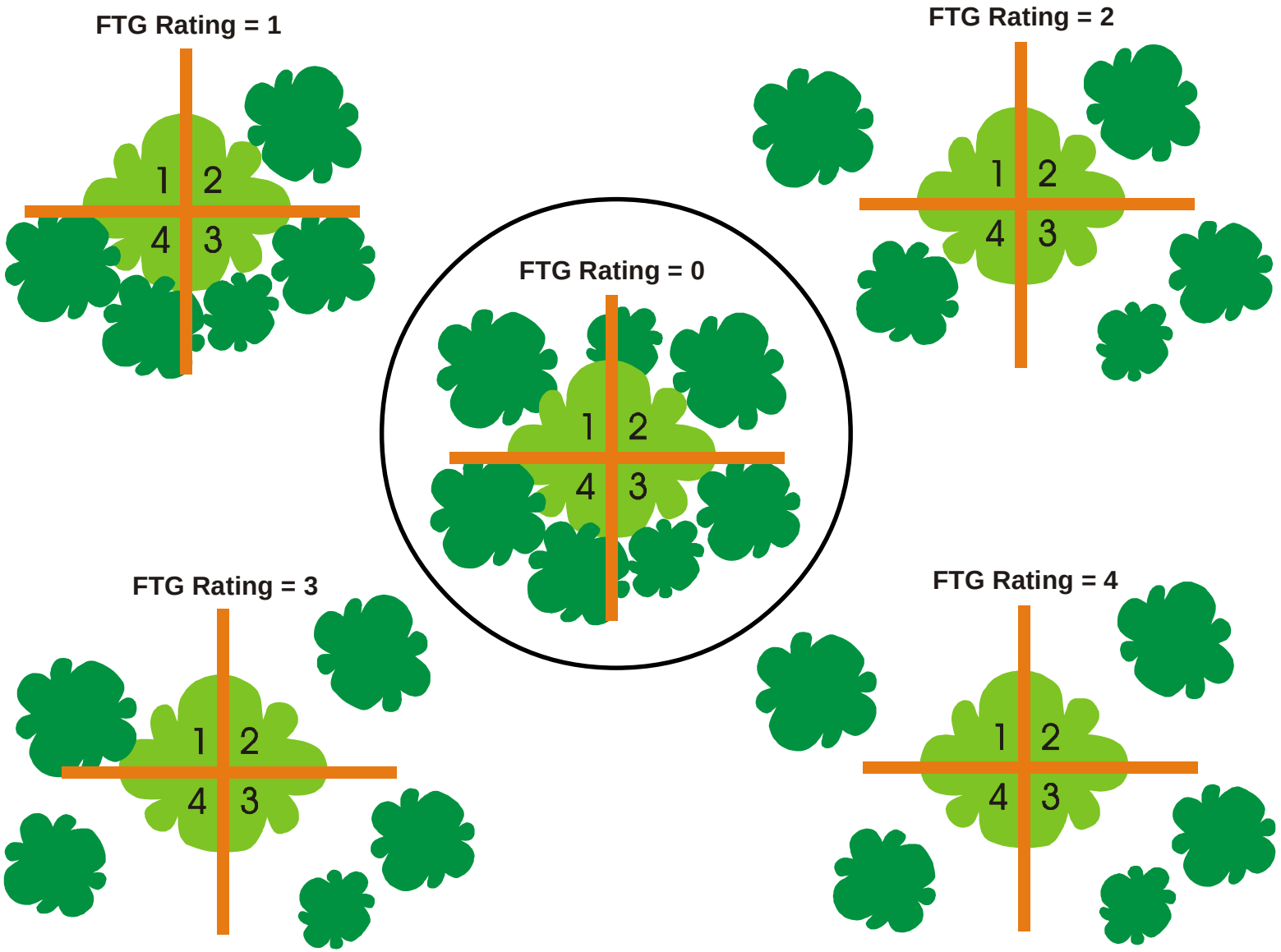
As each crop tree is selected, its freedom to grow must be evaluated. This is easily done by looking up at its crown and imagining it divided into quadrants as shown on the following fold-out graphic. An assessment of whether or not the crop tree crown has room to grow is made for each quadrant — if there are crowns of other trees touching the crop tree crown, then there is no freedom to grow or expand. A Free-To-Grow (FTG) rating of 0, 1, 2, 3, or 4 is assigned to each crop tree based on this visual evaluation.

A full crown-touching release means that all trees, in all four quadrants, whose crowns are touching the crop tree crown will be removed from competition. Referred to as a four-sided release, this opening up of the growing space around the crop tree crown focuses resources necessary for accelerated growth on the trees with the greatest potential to produce desired benefits.

In some cases, when two crop trees occur close together, it is acceptable to consider both trees as one crown and then release fully around the two. This gives each tree only a 3-sided release, but removing all trees around the dual crowns eliminates enough interference to allow the two crop trees to respond well to release.

A crown-touching release should be considered once trees have attained a height of 25 feet.

CROP TREE MANAGEMENT — FREE TO GROW RATINGS

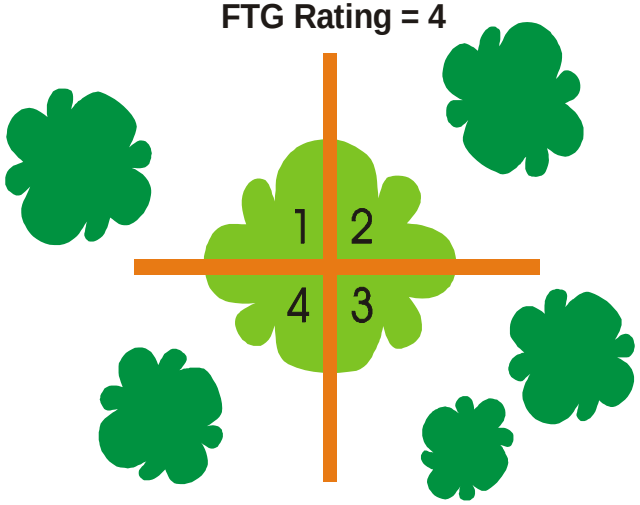


CROP TREE MANAGEMENT — CROWN-TOUCHING RELEASE

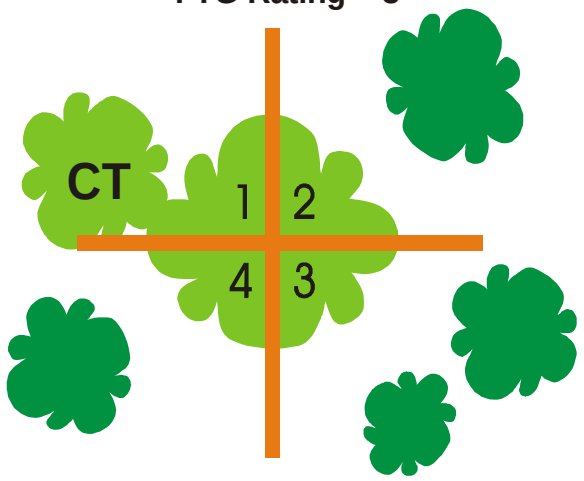
FOR OPTIMUM GROWTH
A 4-SIDED RELEASE IS REQUIRED

the only exception is . . .

FTG Rating = 4



FTG Rating = 3



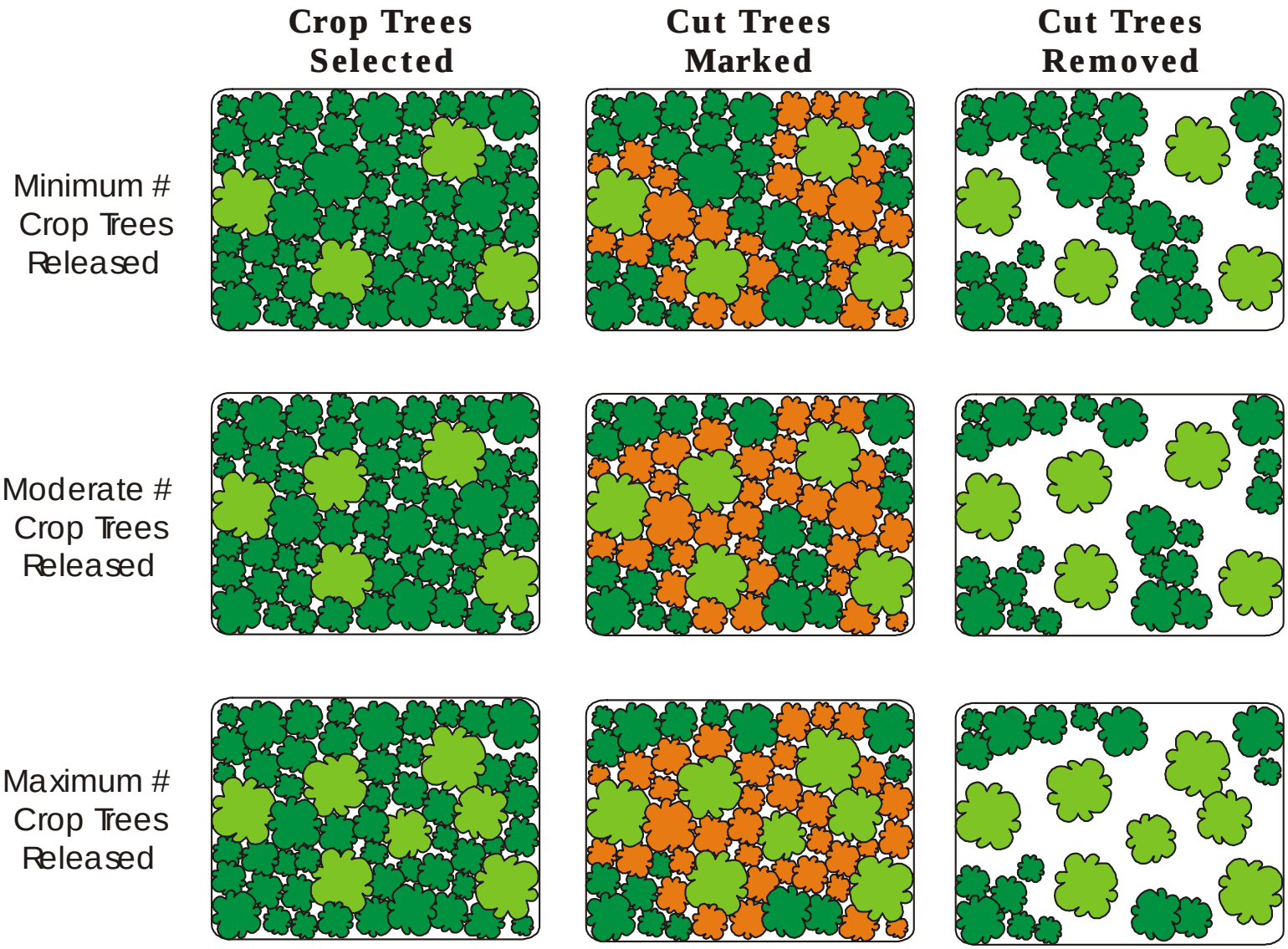
a 3-sided release when the competing tree retained is another crop tree.

APPENDIX B

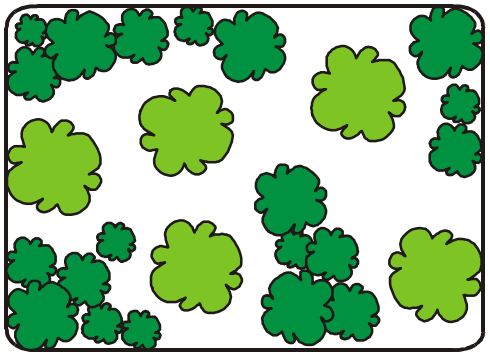
Crop Tree Management allows flexibility in managing how treatment areas will look by varying the intensities of cutting. The following fold-out illustrates how to adjust the degree of thinning by adjusting the number of crop trees released.

It is important that the intensity of treatment is done correctly by reducing the number of crop trees released instead of by reducing the amount of release given to each crop tree. The optimum rapid growth that Crop Tree Management produces is only obtained by providing a full crown-touching release to each crop tree.

CROP TREE MANAGEMENT — VARIOUS INTENSITIES OF TREATMENT

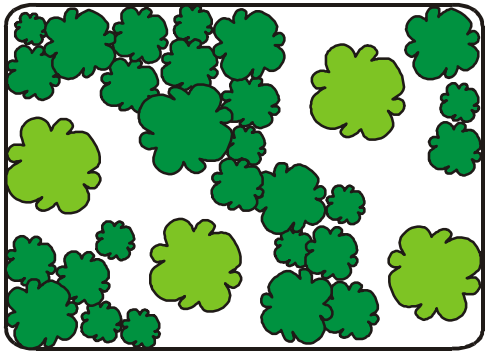

Crop Trees Selected
Cut Trees Marked
Cut Trees Removed
Minimum # Crop Trees Released
Moderate # Crop Trees Released
Maximum # Crop Trees Released

IF THIS CUTTING IS TOO HEAVY . . . .



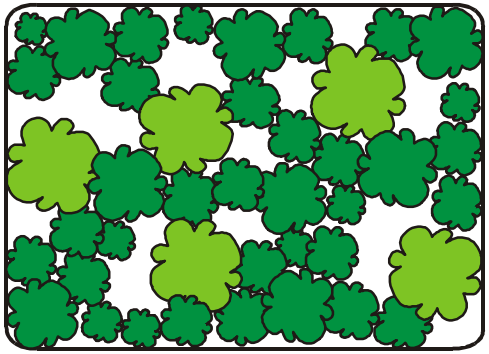
then reduce the intensity of cut by . . . .

reducing the number of crop trees selected for release . . .



CORRECT

NOT



INCORRECT

reducing the amount of release given to each crop tree.

APPENDIX C

Because Crop Tree Management focuses on individual trees, it is important to have an appropriate way of evaluating growth. Individual tree diameter growth expressed in inches per decade is a viable means of measuring growth rates and responses. The reproducible CROP TREE GROWTH tally sheet in the back pocket of this publication explains the process. It can be used to record and monitor crop tree growth.

Monitoring Crop Tree Diameter Growth

If you are growing trees to produce a timber product, it is important to know your actions are producing the results you need. To evaluate the performance of your timber crop trees, it is necessary to monitor the growth of a sample of those crop trees. This can easily be done by establishing a set of 10 trees of the same species and of similar size, age, vigor, and free-to-grow rating. The site productivity of the sample crop tree locations should also be similar.

Follow the instructions on the back of the CROP TREE GROWTH tally sheet (back pocket insert) and record the data for your crop trees. Compare your results with the growth rate comparison charts that follow.

The charts contain individual tree (diameter at breast height) growth information that is intended as an aid to predicting how released and unreleased crop trees will grow. This information is compiled from research studies and monitored demonstration areas with adjustments based on experience. It is applicable in West Virginia, eastern Ohio, southwestern Pennsylvania, and western Maryland. Growth rates are indicated in inches per decade. This estimating aid is intended for use on trees with healthy crowns judged to be capable of responding to release.

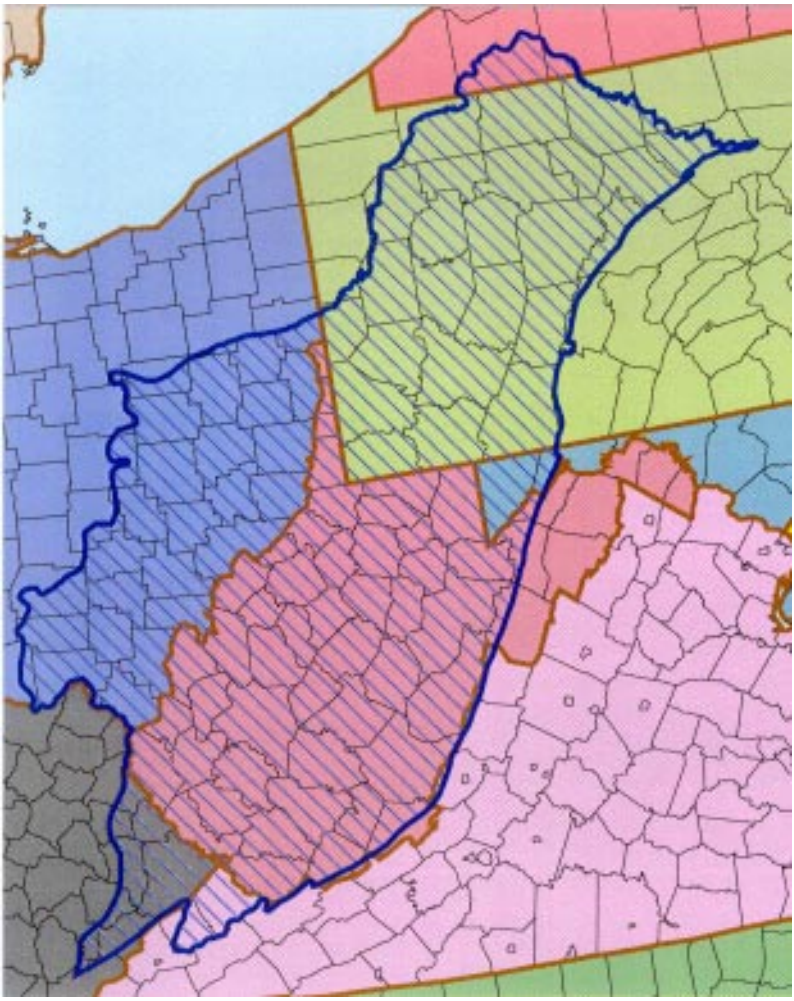
Growth Rates on Average Sites for the Species

(Average growth rate, inches per decade)

Species and Site Location*	Age**	Unreleased (FTG 0)	Released (FTG 3 or 4)
Red oak–9	16 to 26	1.8	2.8
Red oak–6	35 to 45	—	4.0
Red oak–2	55 to 65	2.1	3.6
Red oak–5	75+	2.2	3.2
Yellow-poplar–3	12 to 22	2.9	4.0
Yellow-poplar–5	75+	2.0	3.6
Black cherry–3	12 to 22	2.4	3.6
Black cherry–5	75+	2.4	2.4
Sugar maple–6	25 to 35	—	3.5
Sugar maple–5	75+	1.4	2.0
Red maple–5	75+	2.2	2.8
Beech	75+	1.4	3.0
Hickory–10	63 to 70	—	1.5
White oak–10	63 to 70	—	2.5
White oak–1	80+	1.2	2.0
Scarlet oak–1	55+	1.7	2.3
Black oak–7	50	2.0	3.5
Black oak–1	80+	1.5	1.8
Chestnut oak–9	16 to 26	1.7	2.3
Chestnut oak–1	80+	1.5	2.3

* See Page 87.

** This column lists the range of ages for the crop trees in a specific research study or demonstration area. Where there is greater variation in crop tree age, or if it is less precisely known (generally older trees), the age is listed as greater than a minimum.



Area of Applicability

Central Appalachian Region
of the United States

Growth Rates on Poorer than Average Sites for the Species

(Average growth rate, inches per decade)

Species and Site Location*	Age**	Unreleased (FTG 0)	Released (FTG 3 or 4)
Black cherry–5	60 to 70	1.1	1.8
Black cherry–8	75 to 82	0.7	1.6
White ash–6	25 to 35	—	2.5
White ash–8	75 to 82	—	1.6
Yellow-poplar–2	55 to 65	1.4	2.7
Red oak–8	75 to 82	1.9	2.4
Red maple–8	75 to 82	1.4	2.3

*This column lists the species and the associated site location of the growth information as referenced in the box below.

** This column lists the range of ages for the crop trees in a specific research study or demonstration area. Where there is greater variation in crop tree age, or if it is less precisely known (generally older trees), the age is listed as greater than a minimum.

Site#	Location
1	Camp Creek Crop Tree Demonstration Area – WV
2	Coopers Rock Crop Tree Demonstration Area – WV
3	Fernow Experimental Forest – WV
4	Fernow Experimental Forest and Monongahela National Forest – WV
5	Monongahela National Forest (Northeastern Research Station Plots) – WV
6	Perkey Tree Farm – PA
7	Raystown Lake Crop Tree Demonstration Area – MD
8	Savage River Crop Tree Demonstration Area – MD
9	Savage River State Forest (Northeastern Research Station Plots) – MD
10	Skidmore Crop Tree Demonstration Area – WV

APPENDIX D

The folowing information is offered as additional help in identifying the four species of hickories addressed in this guide. The tight-bark hickories can be difficult to differentiate among, so they often warrant more detailed evaluation and observation of specific characteristics when making species determinations. Knowing what to look for will make the task a little easier.

Help for Identifying Hickories (Shagbark, Mockernut, Pignut, and Bitternut)

This field guide addresses timber, wildlife, and aesthetic characteristics of four species of hickory – shagbark, mockernut, pignut, and bitternut. Generally, it is important for crop tree managers to be able to distinguish tree species using bark characteristics. With most tree species, this is a practical skill to obtain. However, with three of the four hickories included in this guide, bark characteristics alone may not be sufficient for accurate identification.

The shagbark hickory is easily distinguishable by the shaggy bark plates that noticeably hang from the trunk of the tree. To assist in the tougher job of distinguishing between the three tight-bark hickories covered in this guide, the following can be used to help refine identification:

Bark Characteristics		
Mockernut	**Pignut**	**Bitternut**
Tight bark, interlacing ridges Sometimes has rich chocolate color beneath bark	Tight bark, interlacing ridges	Tight bark, interlacing ridges

The characteristic shaggy bark of shagbark hickory makes it easy to distinguish from the tight-bark hickories.

Mockernut hickory bark is sometimes distinguishable from other tight-bark hickories by the chocolate color that lies beneath the bark surface. A pocket knife can be used to expose a small area where the rich chocolate color will be revealed.

Fruit Characteristics

Mockernut	Pignut	Bitternut
Husk 1/8” to 1/4” thick, splitting nearly to the base of the 4-angled nut	Thin husk splitting only to 3/4 length of the unridged nut	Thin husk

Terminal Bud Characteristics

Mockernut	Pignut	Bitternut
1/2” to 3/4” long; egg-shaped; bud scales imbricate; early dropping of yellow to tan, silky outer bud scales	1/4” to 1/2” long; bud scales imbricate; winter dropping of glabrous, reddish-brown outer scales	1/2” long; bud scales valvate; slender; bright, sulfur-yellow color

The imbricate (overlapping) scales on the buds of mockernut and pignut help separate these two hickories from bitternut hickory.

Viewing the buds of pole- and sawtimber-size tight-bark hickories from the ground can be enhanced with binoculars. Good visual examination that clearly reveals the distinctively different shape and color of bitternut hickory distinguishes it from pignut and mockernut hickories.

The valvate (edge-to-edge, not overlapping) bud scales along with the yellow color and slender shape of the bitternut buds help to separate it from pignut and mockernut hickory.

Leaf Characteristics		
Mockernut	**Pignut**	**Bitternut**
7-9 leaflets, hairy beneath; hairy, stout rachis	5 leaflets (7 rarely); rachis smooth	7-11 leaflets, lightly hairy; slender rachis

Habitat Characteristics		
Mockernut	**Pignut**	**Bitternut**
Dry, upland forests	Dry, upland forests	Moist, deep soils

APPENDIX E

Several factors affect natural regeneration. The chart that follows summarizes information about seed production and germination for the sixteen species covered in this field guide. In some cases, information is not available, and is so noted with a " – " on the chart.

Characteristics Affecting Seed Production and Germination

Species	Seed Longevity in Soil (Years)	Frequency of Good Seed Crop (Years)	Initial Seed-Bearing Age	Optimum Seed-Bearing Age	Tree Longevity* (Years)
Black Cherry	3	1-5	10	30-100	180+
White Ash	3	3-5	20	–	–
Yellow-poplar	8	1	15-20	Up to 220	300
Red Oak	=	2-5	25	50+	200+
Black Walnut	=	2-5	10	30-100	150+
Sugar Maple	2	2-5	40	40-60/light 70-100/med.	300-400
Red Maple	=	1	4	–	150
Beech	=	2-8	40	60+	300-400
White Oak	=	4-10	20	50-200	500+
Chestnut Oak	=	4-5	20	–	200
Scarlet Oak	=	3-5	20	50+	<other oaks
Black Oak	=	2-3	20	40-75	150-200
Shagbark Hickory	=	1-3	40	60-200	200+
Mockernut Hickory	=	2-3	25	40-125	200+
Pignut Hickory	=	1-2	30	75-200	200+
Bitternut Hickory	=	3-5	30	50-125	200

* Tree growth will slow down, and vigor and seed production will decline before these ages.

– Information unavailable.

= Most seeds germinate within 1 year after seedfall.

SOURCES OF INFORMATION

Burns, Russell M.; Barbara H. Honkala, tech. coords. 1990. Silvics of North America: 2, Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. Vol. 2, 877 p.

Carvell, Kenneth L.; Perkey, Arlyn W. 1997. Using Diagnostic Plants To Evaluate Site Class. NA-TP-03-97, Northeastern Area, State and Private Forestry.

Carvell, Kenneth L.; Koch, C.B. 1963. Black Cherry – Its Abundance, Quality, and Rate of Growth in the Oak-Hickory and Cove Forests of West Virginia. West Virginia University Agricultural Experiment Station. Bulletin 485. 12 p.

Hicks, Ray R. 1998. Ecology and Management of Central Hardwood Forests. John Wiley & Sons, Inc., 412 p.

Heiligmann, Randall B. 1997. Herbicides Commonly Used for Controlling Undesirable Trees, Shrubs, and Vines in Your Woodland. Ohio State Univ. Ext. Fact Sheet F-45 Supplement-97. 5p.

Kelty, Matthew J. 1988. Sources of Hardwood Regeneration and Factors that Influence These Sources. p. 17-30 in Proceedings: Guidelines for Regenerating Appalachian Hardwood Stands. Smith, H. Clay, Perkey, A. W., and Kidd, W. E., Jr., eds.

Keys, Jr., J.; Carpenter, C.; Hooks, S.; Koenig, F.; McNab, W.H.; Russell, W.; Smith, M.L. 1995. Ecological Units of the Eastern United States – first approximation (map and booklet of map unit tables), Atlanta, GA: U.S. Department of Agriculture, Forest Service.

Kidd, William E.; Smith, H. Clay. 1989. Woodlot Management: Helping It Grow. West Virginia University Extension Service.

Kochenderfer, Jeffrey D.; Zedaker, Shepard M.; Johnson, James E.; Smith, David Wm.; Miller, Gary W. 2001. Herbicide Hardwood Crop Tree Release in Central West Virginia. North. J. Appl. For. 18(2):46-54.

Lamson, N.I.; H.C. Smith. 1989. Crown Release Increases Growth of 12-Year-Old Black Cherry and Yellow-Poplar Crop Trees. USDA For. Serv. Res. Pap. NE-622. 7p.

Lamson, N.I.; H.C. Smith; A.W. Perkey; S.M. Brock. 1990. Crown Release Increases Growth of Crop Trees. USDA For. Serv. Res. Pap. NE-635. 8 p.

Lamson, Neil.I; Smith, H. Clay. 1988. Thinning Cherry-Maple Stands in West Virginia: 5-Year Results. Res. Pap. NE-615. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 7 p.

Leopold, Donald J.; McComb, William C.; Muller, Robert N. 1998. Trees of the Central Hardwood Forests of North America.

Miller, Gary W. 1996. Epicormic Branching on Central Appalachian Hardwoods 10 Years After Deferment Cutting. Res. Pap. NE-702. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 9 p.

Miller, Gary W. 1997. Stand Dynamics in 60-Year-Old Allegheny Hardwoods After Thinning. Can. J. For. Res. 27: 1645-1657.

Miller, Gary W.; Kochenderfer, James N. 1998. Maintaining Species Diversity in the Central Appalachians. Journal of Forestry 96(7):28-33.

Miller, Gary W. 2000. Effect of Crown Growing Space on the Development of Young Hardwood Crop Trees. North. J. Appl. For. 17(1):25-35.

Perkey, Arlyn W.; Wilkins, Brenda L.; Smith, H. Clay. 1994. Crop Tree Management In Eastern Hardwoods. NA-TP-19-93, Northeastern Area, State and Private Forestry.

Perkey, A. W.; Onken, A. 2000. A Decade at a Crop Tree Demonstration Area. Forest Management Update. 20: 1-13.

Smith, H. Clay; Della-Bianca, Lino; Fleming, Harvey. 1983. Appalachian Mixed Hardwoods. P. 141-144, in Burns, Russell M., tech. comp., Silvicultural Systems for the Major Forest Types on the United States, Agric. Handb. No. 445. Washington, DC: U.S. Department of Agriculture, Forest Service; 191 p.

Smith, H. Clay; and Lamson, N.I. 1991. Releasing 75- to 80-Year-Old Appalachian Hardwood Sawtimber Trees: 5-year d.b.h. Response. P. 402-413 in Proc. 8th Cent. Hard. For. Conf., McCormick, L.H. and K.W. Gottschalk, eds.

Smith, H. Clay; Miller, Gary W.; Lamson, Neil I. 1994. Crop-Tree Release Thinning in 65-Year-Old Commercial Cherry-Maple Stands (5-Year Results). Res. Pap. NE-694. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 11 p.

Trimble, George R., Jr. 1975. Summaries of Some Silvical Characteristics of Several Appalachian Hardwood Trees. Northeastern Forest Experiment Station, Upper Darby, PA, 5 p.

U.S. Department of Agriculture, Forest Service. 1979. A Guide to Common Insects and Diseases of Forest Trees in the Northeastern United States. Northeast. Area State Priv. For., For. Insect and Disease Management, Broomall, PA. P.123, illus. (USDA For. Serv., Northeast. Area State Priv. For. Publ. NA-FR-4).

Instructions for Using this Form to Monitor Crop Tree Growth

Trees grow during the spring and summer while they are in leaf. In autumn, when all the leaves have fallen, growth stops and does not begin again until new leaves appear the following spring. This form is designed so that the growth of crop trees is recorded during the growing season in which it occurred. It doesn't matter exactly when during the dormant season the remeasurements are done, as long as it is sometime between October and April while there are no leaves on the trees. Remeasure once each year. Track the growth of crop trees one growing season at a time, and establish a valuable record of consecutive growth data that can be used to help make future management decisions.

1. Select ten (10) similar crop trees in relatively close proximity to each other that will be easy to relocate and remeasure. Choose trees of the same species with about the same free-to-grow rating.* The trees should be similar in diameter (for example, from 10" to 14" DBH**).

Note: The growth of several groups of crop trees can be monitored, depending on how many sets of 10 similar crop trees are available for selection. It is interesting to observe how factors like location, species, weather, and freedom to grow affect growth among various groups of trees.

2. Paint a horizontal line on each tree at DBH and number the trees consecutively from 1 to 10. Tube paint works well. See photo below.

Note: If there are more than one group of 10 trees, do not renumber 1-10 for each group. Continue consecutive numbering so that each tree is uniquely identified and there is no duplication of numbers.

3. During the initial dormant season, measure the diameters of all 10 crop trees with a diameter tape at the established paint line and record it in the first DBH column (See **Example** below). Make sure the diameter tape is pulled snugly against the tree with no sagging. Loose fits and sags result in exaggerated measurements.

4. During the following dormant season, measure the diameters of the 10 trees again and record it in the next column. Repeat measurements once each year, and always be sure to measure at the paint line each time. Again, make sure the tape is wrapped snugly around the tree.

5. Calculate the growth for each growing season for every tree by subtracting the previous year's recorded DBH from the current DBH. Sum the annual growth for the 10 trees to obtain yearly growth in inches for the 10 trees. Sum over 10 years and divide by 10 for the average growth per year in inches per decade.

Numbered Crop Tree

Important Note

To accurately record growth during the year when it occurred, label DBH column according to the year in which the dormant season began.

Example

DBH measurement taken between October 2000 and April 2001, label as 2000 DBH.

Example

DBH 2000	DBH 2001	GRO
18.4	18.8	.4
14.5	15.0	.5
17.8	18.1	.3
15.4	15.8	.4
14.8	15.3	.5
12.8	13.0	.2
12.8	13.1	.3
17.4	17.6	.2
16.0	16.3	.3
17.5	17.8	.3
Total Growth –		3.4

* Free-to-grow information is contained in Crop Tree Management Quick Reference and Crop Tree Field Guide, both available from the USDA Forest Service, 180 Canfield Street, Morgantown, WV 26505.

** DBH (Diameter at Breast Height – 4.5 feet above the ground).

CROP TREE GROWTH

(See Instructions on Back)

LANDOWNER: **DATE:**

STAND HISTORY:

STAND NUMBER: **ACRES:** **AGE:**

TREE	SPE-CIES	FTG	DBH 20	DBH 20	GRO	DBH 20	GRO	DBH 20	GRO	DBH 20	GRO	DBH 20	GRO	TOTAL GRO
TOTALS														

TREE	SPE-CIES	FTG	DBH 20	DBH 20	GRO	DBH 20	GRO	DBH 20	GRO	DBH 20	GRO	DBH 20	GRO	TOTAL GRO
TOTALS														

Notes:

USDA Forest Service, NA-S&PF, Morgantown, WV
(Revised October 2001)